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A study on interaction-driven comparison between analog and digital gaming control interface on smartphone

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ABSTRACT

This paper aims to find empirical evidence of effectiveness levels such as comfort, efficiency, and accuracy between analog and digital interface on smartphone game control. According to many video games converted to the mobile game environment, providing virtual input and output control of the *Tap-only affords* basis raises the issue whether a virtual interface on smartphone games is efficient, effective and useful regardless type of games provided by game developers. During the stream of changes from analog to digital platforms, there has not been yet raised the significant questions whether the shift of touchscreen-based input control has provided users with more efficient interaction and experiences compared with two simulations between analog and digital interface. In order to approach the evaluation of user's satisfactory level, errors, and accuracy rate though the comparisons of user interfaces between digital (touchscreen) and analog controller in the smartphone games, this study implemented the Pilot Study comprised of two different groups as a small-scale experiment. Participants' behaviors were observed as how they control input system with a finger(s) touch and a game controller. The performance by users was also observed during a task to see how users make errors or mistakes concerning interface design in both digital and analog controls. This study found that touchscreen was more effective with playing a game as directed input control task and multi-input control tasks with a game controller. However, the touchscreen was more effective and easier to interact with a single input control, especially continued the movement for sticking/tapping/swiping finger gestures on the touchscreen showed the most effective circumstance in smartphone game environment.

With the findings of the Pilot Study, this study approached the research direction to discover an empirical evidence if the result of the Pilot Study is positive in the same manner with input control tasks from the bigger group. In addition, the study intended to find effectiveness from different conditions with an input task control between finger touch and physical touch controller. The usability test was implemented by a larger number of groups (total 81 participants divided into 9 groups, 9 participants per each group) for finding effectiveness and satisfactory level of touch-based control between direct input control *(finger touch basis)* and indirect input control with attached analog controls *(Touch pen and joypad)* on the smartphone touchscreen. Two different games were divided into two groups based on one and two hands input control during the gameplay, and each group was assigned to different control condition for playing the game. The collected data and measured values were evaluated by the statistical analysis. The result appeared that direct touch screen interaction is more effective on two hands input control task. Using an indirect physical input control *(Touch pen and Joypad)* was more effective on one hand touchscreen. This result showed different result from the Pilot Study regarding the physical input control condition. However, this main study found that one single input control is more effective, comfortable and accurate on one hand control with an analog input control attached to the touch-screen interface. Moreover, a touch-based input control was more satisfied with two hands input control condition such as shooting and movement simultaneously. Game score and level achievement were not significantly different between two hands control groups, but the group E-1 in same input control condition with given 15 minutes' pre-exercise appeared an outstanding value on game score and accuracy rating due to the familiarity of perception through the repeated gameplay.

Through the findings, this study concluded that a significant concern to smartphone developers and designers in human-computer interaction needs to be discussed for how digital interface is more efficient than analog, and/or when analog interface works better than digital. For the consideration of types of the smartphone game, one hand control with an analog control would be more effective for the game which requires a control of direction/movement of speed, accuracy and completion time. Two hands input control with finger gestures directly interacted with a touchscreen would be more effective for the type of strategy games which requires users to oversee multi-tasks input control such as simultaneous control with shooting, and change of direction and movement. This study suggests that smartphone game needs to consider game design for touchscreen environment-friendly, but both finger-touch-basis and analog touch-based input control need to consider.

CHAPTER I. INTRODUCTION

1.1. Research Background

According to the digital revolution in the transition from analog to the digital interface, computer devices have introduced user interfaces with a digital platform for users' implementation. Some products still provide an analog interface such as a knob control and buttons while many mechanic products are transited by digital touchscreen interface for the control system. As human are analog creatures, people obtain knowledge and information through learning experiences. Using any new hardware and software is a challenge in learning experience for the first time. Some users become familiar with *how-to-do* through the physical and mental interaction by human senses (sight, hearing and touch). Some users keep having a difficult time in their experiences of transition from analog to digital environment regardless of prior experienced knowledge. Empirical research has claimed various findings of user-centered design in which how products can be more efficient for better communication and interaction between users and devices (Darejeh, 2013; Norman, 1998; 2013; Tsagarakis & Caldwell, 2013; ROSLI, 2015; Sethumadhavan, 2016).

A touch screen in mobile technology is another impact on studying as how digital interface has been changed to the recent graphical era. Mobile technology has changed user's environment based on Internet services and at least 2 billion people by 2012 had internet access through their smartphone. The *Internet of Things* (IoT) is the most recent technological innovation, and smartphone is moving towards being substitutive as multiple interactions. Until the smartphone was introduced in 2007, a mobile phone was for only talking and texting. The first smartphones were not for the concept of old fashion- talking to someone. It introduced a lot more functionality for personal, business, and entertainment. Today, smartphone means more than a phone. We often use it as a personal assistant such as buying products through online shopping, finding a location on the Google map, watching videos, sharing photos in social media and blogs, writing notes in the conference, checking and sending emails, monitoring health activity, playing games and so on.

Product design of the mobile phone has also changed to provide mobile computing system. Significant changes to the mobile phone with a touchscreen technology for the digital without *"Being Digital"* written by Negroponte (1995) was a major key point to rethink the relationship between analog physics and digital technology. His concerns of being digital are not opposite to analog concept. Being digital should be an innovated convergence of technology relationship between hardware and software. However, even straightforward and common task on a digital interface can be problematic to smartphone users. A smartphone moving towards portable computing system does not mean that user interface and interaction would be expected with the same performance from the desktop computers. For instance, using a Microsoft Word allows users working on both a desktop computer and a smartphone though the 'Cloud.' Creating a document with typing in a virtual keyboard and making a table on a small screen is not the same experience from the desktop. Users may have difficulties in executing their performance on a smartphone compared to an efficiency of usability on the desktop computer.

If smartphone users are more familiar with the digital interface, does it mean that the touchscreen is the best solution for using every apps? Some apps require using interface with buttons, and some are based on a gestural action with fingers. Since an analog interface has been transferred to a digital interface, interface control panel in digital apparatus and products is comprised of graphic icons. Digital interface with a preference setting on the surface enables users to encounter with operating and monitoring system. During the stream of changes from analog to digital platforms, no one has brought up the significant questions whether the changes provides users with more efficient interaction and experiences compared with two models between analog and digital interface.

Thus, the digital evolution is an ongoing process and understanding its technology as to how we know, how we use, and how we change. A significant concern to smartphone developers and designers in human-computer interaction needs to be discussed for how digital interface is more efficient than analog, and/or when analog interface works better than digital.

1.2. Research Purpose

The main purpose of this study is to find empirical evidence if a digital touchscreen interface in a smartphone is more efficient than an analog interface for users in a way they adjust the input controls while users are playing a smartphone game. The following objectives of this study are;

- to observe user's behaviors of input control between analog and digital interface design.
- to find users responding of accuracy, swiftness and effectiveness between analog and digital interface.
- to compare perceptive cognition between touchscreen and game controller (Visual, haptic and audio).

Research Questions:

Since a smartphone provides a touchscreen for the navigation and operations, does it mean that digital interface is more effective for all operating system than an analog interface? How analog interface became digital and how digital input control changed a smartphone game differently? Is there any empirical evidence comparing digital and analog interface on a smartphone since various types of the smartphone game controller have been introduced in the gaming market?

Research Hypothesis:

According to the touchscreen interaction as a user-friendly basis on using a smartphone, various applications on the smartphone provide a digital interface on the touch screen. If smartphone users were experienced with a digital touchscreen interface, they would have a positive experience through playing a smartphone game on a touchscreen as well. However, analog game controllers were popular before the smartphone introduced the touch-based input control screen. Is it true that the analog controller would work better in the smartphone environment or not?

CHAPTER II. LITERATURE REVIEW

2.1. Overview of Gaming Environment

Digital Games are mass-market commercial products producing various entertainment activities with digital media. As the mobile media industry technology advances with enhanced graphic features, digital gaming in various media contents has provided consumers superior gaming experiences. Children's interaction with technology became, even more, important to the learning activity, and adults are also part of family games as engaging with their kids. Playing video games brings families together, and it became a positive way in today's social context. Playing a video game in a family means an interactional resource as intergenerational encounters rather than a problem between a generation gap (Aarsand, 2007). Since Nintendo introduced the Wii as the first family console in 2006, 101.52 million consoles have been sold in worldwide (Consolidated Sales Transition by Region). Gaming environment also has been changed by digital platform as portable and mobile adoption for smartphone users. According to a study by the *Ofcom*, the use of the Internet, mobile phone, and iPods has declined the population of young children's use of DVDs and video game consoles (Edgecliffe-Johnson, 2007). While video games were still popular in the game industry by 2010, smartphone games have introduced a similar type of games from the computer and video games last four years. Since then, smartphone games have appeared as social activities engaged by other users through social media networks. Gaming-based learning, especially, shows more efficient, motivated and engaged with comprehensive in learning methods and learners are engrossed in their games and can spend many hours playing it (Beck & Wade, 2006; Shaffer, 2006).

Digital gaming industry also has expanded its implementation into the education in the classroom, simulation in the science lab, and memory impairment aids in medical therapy. Games are in an excellent relationship with education, especially when dealing with core STEM of the logical and scientific method (Frank Lantz, 2010). Digital computer games are more effective and efficient learning tools regarding learner's attentions to learning engagement (Prensky, 2001). Education by the Digital Game-Based Learning provides learners more conscious brainwork with cognitive responding in pedagogical questions through the games. Moreover, games produce principles for intergenerational play and learning that creates more challenges for players in the gaming environment (Steinkuehler & Squire, 2009).

2.1.1. Digital Gaming Industry

With the fast growth of the video game industry, the global video game sales in 2015 are expected to reach $111 billion compared with $93 billion in 2013 (Gartner Your Source for Technology Research and Insight). The U.S. Game industries have grown in a business market up to $25.1 billion in 2010 ESA Annual Report[1]. However, it decreased $22.41 billion in 2014. According to the computer and video game industry, *"the 2014 Essential Facts"* reported by the Entertainment Software Association (ESA) addressed that 59 percent of all ages Americans played video games.[2] Among American households that own a device used to play video games, 68 percent of them played games on a console, 53 percent on a smartphone, and 41 percent used a wireless device. Usage of smartphone devices was increased by 22 percent and 37 percent over 2012. The average game player was 31 years

[1] SaleS, Demographic, anD USage Data eSSential FactS. (n.d.). Retrieved from http://www.theesa.com/wp-content/uploads/2014/10/ESA_EF_2014.pdf
[2] VG Market CEO Michael Gluck Disrupts Video Game Industry. (n.d.). Retrieved from http://millennialmagazine.com/vg-market-ceo-michael-gluck-disrupts-video-game-in

old, and 32 percent users were ranged with age between 18 and 35 years old. However, female gamers age 50 and older increased by 32 percent from 2012 to 2013. On average, adult gamers have played for 16 years.

Casual and social gameplay on the mobile device through the online network has increased greatly over the past few years. Forty-four percent of gamers play casual and social games as a most popular genre on their smartphone, and the number was changed in popularity by 55 percent from 2012 to 2013. Gamers who play more video games compared with three years ago spent less time on watching TV, going to the movies, and watching movies at home. Almost half percent of gamers spent less time for other entertainment media. Moreover, 50 percent of gamers used their consoles to watch movies, and 77 percent played with others for at least one hour per week.

Eighty-seven percent of parents believed that the parental controls available in all new video game consoles were useful. Further, parents imposed usage time limits on video games rather than any other form of entertainment. Ninety-five percent of parents paid attention to the content of the game for their children play while only 56 percent of them said video games were a positive part of their child’s life. Sixty-eight percent of parents believed gameplay provided mental stimulation or education, 58 percent on helping to connect with friends, and 55 percent believe gameplay also helped the family to spend time together. The top five reasons why parents play games with their kids were because it is fun for the entire family, they are asked to, it is an excellent opportunity to socialize with their child, it is good opportunity to monitor game content, and they enjoy playing video games as much as their child does.

The best-selling video games were action and shooter game as over 50 percent of game genres population in 2013 reported by the NPD Group/Retail Tacking Service.[3] The report also addresses that 38.4 percent of the best-selling computer game was a strategy genre. The gaming industry also has increased a market value for three years since 2010. However, video and computer game have dropped the sales market while other delivery formats such as game subscriptions, full digital games, digital add-on content, mobile apps, social network gaming and other physical delivery.

2.1.2. Video Game

The birth of commercial video games was found by Nolan Bushnell, who was the inventor of "PONG," founder of Atari Corporation (Bushnell, 1999). Bushnell developed computer space for the first commercial arcade game based on "SpaceWar" that was designed by vector graphics, but real-time space game. "Hockey" was the first home TV game operated by a game console. Since 2000, video game consoles provided much faster CPU and high quality of video graphic in 3D. Video and PC game environments were arranged with a variety of users who seek joyful entertainment with friends, family or oneself (Sony upgrades its play station 2, 2003). People played the video games or arcade machine in a group together until the PC games became more popular with a social network. In early 2000, PC game connected via the internet to the team strategy became more popular among virtual users (War and video games, 2011). As the most popular strategy PC game, "World of Warcraft" took $ 700 million with 4 million subscribers in 2005 first launch and it has increased the market value up to $759 million in 2015. *Figure II-1* shows the number of

[3] U.S. Computer and Video Game Dollar Sale Growth (Sales, Demographic, and Usage Data Essential Facts, 2014): Retrieved from http://www.theesa.com/wp-content/uploads/2014/10/ESA_EF_2014.pdf

World of Warcraft subscribers for last ten years. Since 2010, it slowly declines the number of users, but the change of subscriber's number was dramatically dropped as 5.5 million subscribers in 2015 compared with 10 million in 2014. This phenomenon caused by other competitors introducing dynamic and interactive with graphic simulation in video and PC platform. Moreover, thousands number of mobile games have replaced the gaming entrainment as an independent time-consuming via social media which is relevant to the smartphone addiction with digital media syndrome (Lin et al., 2014).

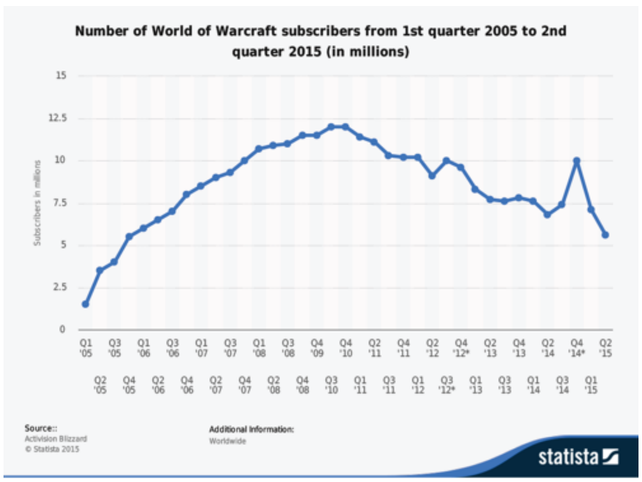


Figure II-1. Number of World of Warcraft subscribers (WoW subscription number 2015)[4]

A history of the video gaming consoles

The history of video games is related to the development of computers since the early 1950s. In the 1970s and 1980s, video games launched with gaming consoles and home computer games. The first computer game, "Tic-Tac-Toe" was invented by Alexander S. Douglas for the EDSAC in 1952 (Bryce and Rutter, 2003). William Higinbotham, a physicist at the Brookhaven National Laboratory, invented "Tennis for Two" which was an essential simulation of the interactive electronic game in 1958 (Brookhaven National Laboratory, n.d.).

[4] Image retrieved from http://www.statista.com/statistics/276601/number-of-world-of-warcraft-subscribers-by-quarter/

"Spacewar!" run on a PDP-1 was written by a research team of MIT student in 1961. It is one of the earliest digital computer video game.

A major shift in the evolution of digital game with gaming console arrived in 1967. *Table II-1* addresses a chronological history of the invention for the video game consoles. Before the 1980s, gaming console was designed for the simple task such as adjusting movement with a knob. As computer system developed in the '80s, gaming console provided a high quality of visual graphic in both 2D and 3D with a more enhanced game control system. With computer development in the 1990s, a new concept of the game console released a small portable device but limited gaming performance by the operating system. Instead, gaming console with more dynamic performance with gaming controllers was developed in the late '90s and 2000s. The Wii by Nintendo and PlayStation by Sony provided users new experience with a controller for playing a game more dynamically.

Table II-1. History of gaming console (Evolution of video game controllers-Stanford University)[5]

Year	Name of Gaming console
1967	***Brown Box:*** designed by Ralph Baer and his coworkers (the first video-game console that works on a standard television).
1972	***Odyssey:*** the first commercial video game console. The system used six cartridges to play up to 12 games featuring dots and lines on the screen.
1975	***Pong:*** After Nolan Bushnell founds 'Atari' in 1975, the company has its first big hit with the arcade game, 'Pong.'
1980	***Intellivision:*** Mattel released the 'Intellivision' in 1980, the first challenge to Atari's dominance and the start of an early '80s console war between Atari and Mattel. The Intellivision features slightly better graphics than the Atari 2600, as well as the first synthesized voice in a video game.
1985	***Nintendo:*** Nintendo, originally a Japanese playing-card company, retailers are skeptical at first about marketing with popular in-house titles like Super Mario Bros, Metroid.

[5] Video game console: Retrieved from https://en.wikipedia.org/wiki/Video_game_console.

Table II-1. Continued

1989	***Game Boy:*** Nintendo introduced as its second smash hit with the introduction of the Game Boy in 1989. The first major handheld game console as a black and white LCD screen.
1991	***Super NES:*** Nintendo introduced its own offering with the Super Nintendo Entertainment System. Super Nintendo eclipses Genesis to become the top selling 16-bit system in the U.S.
1995	***PlayStation:*** The launch of Sony's PlayStation arrived the most popular console of the 32-bit era of video games. Games introduced three-dimensional gameplay for the first time over the 2D games that dominated the 16-bit and earlier system. With CD-ROM technology, the price of PlayStation games drops dramatically from those of cartridge-based games.
2000	***PlayStation 2:*** SONY released the PlayStation 2, the first 128-bit system. It features backwards-compatibility- the ability to play older 32-bit PlayStation games on the PS2 – and also functions as a DVD player.
2001	***Xbox:*** The first independent foray into the console market in 2001. The Xbox console allows for greater performance when compared to other 128-bit consoles like the PlayStation 2 and Nintendo GameCube.
2004	***Nintendo DS**:* Nintendo introduced the Nintendo DS, an attempt to integrate more computing functions into its handheld gaming consoles. The DS features dual screen and touch-screen technology similar to that of a PDA or tablet PC.
2005	***PlayStation Portable:*** Challenge to Game Boy's dominance of the handheld console market, Like the Nintendo DS, the PSP features wireless capability, high-quality graphic, and non-gaming functions
2011	***Wii:*** The Wii is a home video game console released by Nintendo in 2006 and introduced Wii Family Edition in 2011, Wii Mini in 2012. The Will introduced the remote controller which interacts game control as a gestural virtual console.

Game Control Interface

Over the past decades, the gaming industry has dramatically increased the number of consumers and revenue. Video games have developed enhanced hardware and software for providing users immersing experiences while playing a game. User Interface in gaming devices refers to the way players can interact with the game (Input) and receive feedback of their interaction (Output). According to the history of video games (Evolution of Video

Games User Interface), the game controllers are the most significant changes of hardware development for the gaming industry. Primitive games from the early 1950s to 1980s such as "Tennis for Two," "Spacewar!" and "Pong" were controlled by a knob for the only movement. However, video game began with providing a storyline and more complex of game control. For instance, "Donkey Kong (1981)" introduced color graphic elements on the video screen and player needed to control a game character for passing obstacles by jumping and climbing and directed moving. The interface was provided a joystick to control movement and a button to jump. In general function of the game controller, game players interact with the video game by input controller that is a physical device comprising of various buttons and joystick in control interface. Regarding the increasing complexity of video games with the emergence of technologies such as 3D graphics and motion sensors, the user interface of the game controller in video games should not be taken by the same concept any longer as "Brown Box" hooked up with any ordinary TV sets. As more enhanced actions or performances in playing digital games should be considered user's experiences as to how players perceive dynamic visual graphics by controlling the physical interfaces on the screen.

Game controls from the current game technology and product development are comprised of physical, virtual and gesture. PC games interact with input controls through a keyboard and mouse, and video games are accessed by the game consoles. Physical game controllers are a most immersing experience for users to interact input control on playing games (Evolution of Video Game Controllers-Stanford University). Video games have also transferred to portable devices with a small screen game console and built-in software that users can interact with devices by physical buttons or touch screen. The game console is not only affordable itself of a video game, but also it becomes a game controller on being connected to TV set at home through the Bluetooth network. Users enable to navigate game contents with finger- touch on the screen and physical control buttons are attached to the device for playing games.

2.1.3. Mobile Game

A mobile game is based on the video game that users can play a game on a smartphone, PDA, tablet PC and portable game console. A mobile game industry has grown with the population of smartphone users, and total estimated value of mobile games in 2015 is $25 billion reported by the Quarterly Global Games Market (2015 Global Games Market Report). This data underpins that mobile game is one of the significant apps for smartphone users, and the mobile game became the first consideration by game developers (Bhhrmann et al., 2012). Since Apple iPhone introduced Apple Store, the majority of smartphone users began to download any available mobile contents and smartphone games became popular to users and developers. Smartphone games have been developed for not only one single user offline, but also for social activity among the users who are friends, family, or unknown users. As mobile technology has improved its capability significantly, playing games became a part of the social engagement with other users. Up to the result, the report from *Mobile Games Market Growth*[6] addresses the fast growth of mobile games in the consuming market, and the smartphone game revenue is predicted up to over $40 billion next two years.

Until the end of the 20th century, mobile phones' capability was limited to provide gaming experiences as much as video games in terms of limited graphic quality and gaming software. Prior to the introduction of Apple iPhone, cellphone games were not popular among the users even though the number of cell phone owners were as much as smartphone

[6] Mobile Games Market Growth (Report: Mobile to become gaming's biggest market by 2015): Retrieved from http://www.gamesindustry.biz/articles/2014-10-22-report-mobile-to-become-gamings-biggest-market-by-2015

owners now. Early cellphone games were very simple, mono color based on the low-pixel of the small LCD screen *(Figure II-2)*.

Figure II-2. Clone of Tetris on cellphone[7]

Since a smartphone as the new platform introduced various genres and contents from the video and PC games, gaming control interface has appeared as a virtual graphic interface or gestural interaction for input control system. However, virtual interfaces on tablet Pads or smartphones take a certain amount of space on the screen. While users interact with a control panel on the touchscreen, fingers' actions *(touch, swap and move)* can interrupt perceiving visual contents on playing a game. In terms of the type of games specifying the type of gaming user experiences, a game controller should be designed based on accuracy and efficient control satisfaction. Even though smartphone games are listed as much as video games, a smartphone game interface is limited to provide positive experiences compared with physical game controllers. With an absence of physical interaction by user's hands and fingers' performances on the touchscreen, many games are not user-friendly. Missing a haptic from the virtual game controller on the smartphone screen cannot be the same experience as having the physical controller in video games. Since a smartphone is equipped with "G-sensor," smartphone games introduced a new interaction as a gestural for the game control. The G-sensor is detected by a motion sensor that can measure the linear acceleration

[7] Image retrieved from the public domain https://en.wikipedia.org/wiki/List_of_Tetris_variants#/media/File:TI83tris.JPG

of the smartphone. A smartphone detects the linear movements of players with the aid of the accelerometer giving the angular position of a frame reference *(Figure II-3).* *"Accelerometer: The g-sensor is a motion sensor that can measure the linear acceleration of your smartphone. In this case, the letter "G" refers to gravity. In Wiko smartphones, the linear accelerometer is mainly used for display rotation"* (Different Sensor Type, n.d.).

Figure II-3. G-sensor gesture: Apple iPhone 6 Plus[8]

Smartphone game controllers have introduced several accessories with different size, shape, and interface in the gaming market. The controller allows game users to have more dynamic experience in playing smartphone games with a physical controller such as a button, knob, and joystick that are a similar platform as the game console. A typical shape of the controller appears interface on the panel of the controller which enables to attach a smartphone device *(Figure II-4).*

Figure II-4. Smartphone game controller (MOGA Power smartphone game controller):[9]

[8] Image retrieved from the public domain http://www.automoblog.net/2015/10/10/top-10-smartphone-racing-games/
[9] Image retrieved from the public domain http://mikeshouts.com/wp-content/uploads/2013/11/MOGA-Hero-Power-and-Pro-Power-Smartphone-Game-Controllers.jpg

Users can hold a controller while they see the screen like a handed gaming device that access the smartphone game through the Bluetooth. Some games require more accurate and multi-input control simultaneously, and a virtual interface is not easy to control buttons and movement on the touchscreen. Virtual images are overlapped with an input control interface at the smartphone touchscreen, so the screen space is partially abandoned for the virtual interface. Past studies have focused on the touchscreen interface regarding the button size and distance of the screen instead of evaluating built-in touchscreen (Colle and Hiszem, 2004). Kim and Lee (2015) argued that multi-touch interaction techniques be beneficial under a smartphone screen environment so that functions are maintained with a minimum number of buttons as the simple 'Tap-only affords' basis. Existing virtual controllers only adopted the 'Tap only' method from the typical game control standard; however the raised issues are whether a virtual interface on smartphone games is efficient, effective and useful for any games provided by game developers.

Another consideration of the physical controller for smartphone games was mobility. The game controller should be convenient to carry on. *Table II-2* shows different platforms of a mobile control device for a smartphone that was designed for the consideration of mobility. Product designs are affordable to demonstrate mobility: attachable and unified accessories. The 'WynCase,' especially produced a concept of the most intriguing option, aesthetic appeal with customized features for iPhone users. The 'iMpulse is a small key chain unit that is attached to a key holder for users can access to the smartphone easily. The 'Razer Junglecat' is attached to an iPhone as a case that was the same concept as a slide out keyboard.

Table II-2. Smartphone game controller[10]

WynCase	iMpulse	Razer Junglecat
		

2.2. Smartphone User Environment

A significant impact of the digital revolution to date is an invention of the World Wide Web (WWW). The Internet became an information space providing a variety of digital information, allowing users to share digital documents with other users via the Internet. The Internet has influenced numerous digital machines and devices that have changed our society, culture, and environment. People communicate with others by a text message on the smartphone and various business companies for online services have been ranked as top brands in the world. Computer users from different countries became friends via online networks and people share their culture and personal interest beyond the language barrier. All theses factors are the power of the Internet making the world a closer community. We call it as the Internet of Things (IoT): The next technological revolution (Feki, Kawsar, Boussard, & Trappeniers, 2013).

[10] Image retrieved from the public domains
http://kr.aving.net/news/view.php?articleId=460423&Branch_ID=kr&rssid=naver&mn_name=news
http://urtrend.net/mobile/detail.asp?seq=20130131NT002&type=NOTE
https://www.kickstarter.com/projects/wynlabs/wyncase-turn-the-iphone-into-a-true-mobile-gaming
http://www.popco.net/zboard/view.php?id=dica_news&no=10091
https://www.youtube.com/watch?v=8oLOTAx11a8
http://www.playforum.net/webzine/news/view/2666?&page=263

The Internet appearing various formats and digital applications has also reflected on unlimited other domains, and it continues expanding and involving features that a human has not explored yet. An invention of the dictionary word, “Google it” for instance, defines searching in Google engine. Google is a gigantic database for a public resource with updated information in real time. In terms of the Smartphone capability, mobile access enables users to conduct the same tasks as using a desktop computer. A computer launched on a significant role of hardware and software control technology. The Internet is controlled by individual computing characteristics (Stalder, 1999; Feki, Kawsar, Boussard, & Trappeniers, 2013). The spread of computers to individual PCs affects the distribution of controlling power (Beniger 1986). The smartphone technology accommodates an individual user to have various communication methods such as sharing pictures, face-to-face talk, rating a business service, finding a location in GPS, so on. The digital revolution constantly creates a new market for the demands on online communication: online shopping, gaming, entertainment, and social media, and so forth. Even though a digital infrastructure offers people an inclusive transition of a hybrid between online and offline, the digital interaction cannot be replaced by some old school concept.

The digital revolution is an enormous advantage for many different purposes of living. Developers unveil new digital applications every day and technology revolution appears to be evolving out of the user experiences. Thus, the digital evolution is an ongoing process and understanding its technology as to how we know, how we use, and how we change. A significant concern to all developers and designers in human-computer interaction needs to be discussed.

2.2.1. History of the Digital Revolution

The digital revolution or the so-called third industrial revolution between 1950-1970 changed analog, mechanical, and electronic technology to a digital system (Fitzsimmons 1994). The history of digital revolution can be broken into three ears *(see Table II-3)*: batch (1945-1968), command-line (1969-1983) and graphical (1984 and after). According to major development of digital interface in a basis of computer technology, many imperial studies address digital evolution as computing evolvement (Ayers, 1999; Cohen et al., 2008; Ceruzzi 2005). An electronic product has been changed due to the development of technology that offers unlimited possibilities and enormous functionalities through the electronic and digital products. Digital devices have improved user experiences for users to obtain knowledge of accessibility, but digital technology cannot make users wise. In a digital age, users rely on ubiquitous computing tasks everywhere they are. We are confronted with the pervasiveness of information, communication and technology (ICT) in contemporary societies and how the effect our daily lives. Advanced technology and digital product are getting challenged with complexification (Selber, 2004).

Table II-3. A history of the digital revolution (A Brief History of User Interfaces)[11]

Year	Invention	Impact
Batch (1945-1968)	Atanasoff-Berry Computer	The first computer ABC was built in 1937 by Professor John Vincent Atanasoff and graduate student Cliff Berry at Iowa State University.

[11] All references retrieved from the public domains
https://en.wikipedia.org/wiki/Digital_Revolution
http://web.archive.org/web/20081007132355/http://history.sandiego.edu/gen/recording/digital.html
http://www.cs4fn.org/history/digitalrevolution.php
http://www.thepeoplehistory.com/electronics.htm
http://www.lowendmac.com/musings/05/0802.html

Table II-3. continued

	(Vt100 terminal)	This computer was originally built for operators and programmers. The interface of the ABC was designed for users who could be trusted to study for becoming experts later. Ever since computer technology changed easier to understand program languages, information on computers became more personal usages with the keyboard and monitor to communicate between software and human as only direct way.
	Engelbart Mouse	The first prototype of a computer mouse: In the 1960s, Doug Engelbart invented the mouse and introduced a new interaction model as "pointing at things." This invention was the beginning of the Graphic User Interface (GUI).
Command-line (1969-1983)	The Xerox Star	Designer and developers could create digital interface menu to allow the user to discover the software's capabilities. In the 1970s, Xerox moved the further step for the GUI as the desktop metaphor, WYSIWYG *"What you see is what you get style editing"* (Williams and Wilkinson, 1994).
Graphical (1984 and after)	Macintosh	In 1984, Apple released the Macintosh as the personal computer for people to perform day-to-day tasks. The application, "MacPaint," and "MacWrite" were provided and digital information on the screen appears as perceptive information. The visual hierarchy was organized as user-friendly to understand what-to-do without user's knowledge of computer program language. This invention was moderately innovated for users to become affordable to the new interaction with the computer.
	Color Macintosh II	Steve Jobs introduced the first color Macintosh II in 1987, and it was the first "modular." Unlike prior Macintosh models, which were all-in-one, the Mac II series became the first identity of Apple computer supporting high-end line in digital consumption until early 1990.
	World Wide Web	While Apple continued the development of the GUI, the Window PC revolution in the early '90s became popular with the World Wide Web as a new communication paradigm (figure NCSA). Users could experience with new information on the web browser by clicking a mouse and typing a keyboard. This was the beginning of user interface design on a digital platform, and many designers and developers start to consider about "how easy, how fast and how efficient" to use a web browser.
	Discman, CD Walkman	As far as computer and digital technology developed for personal usage, other types of devices were also stimulated by a new concept, user-centered design. Sony introduced the "Walkman" in the '80s. This new product moved from records to cassette tapes that enable users to take music anywhere they were. In the '90s, Sony released a new CD player, "Discman" as "CD Walkman" concept.

Table II-3. continued

Graphical (1984 and after)	Napster	In 1999, Napster brought music and computers together through an online network. Its technology allows users to share their MP3 music files with other users free through online. The software provided a web access to download through each user and interface was comprised of various icons as functional tools to conduct tasks such as search and download between participants.
	iPod	Portable MP3 player totally changed the music industry from analog to digital format. Apple introduced the iPod along with the iTunes. This created another music industry business for users to get an individual song or album. The iPod became the world's best-selling music player. The iPod provided a simple display for a menu to select options, center to select a menu item, play/pause to switch playing music, skip forward/fast forward and skip backward/fast reserve. This all functionality was transformed as a digital operating system.
	T9, BlackBerry	As the technology allows phones to have small LCD screens, people could send a text message to each other via the cellular network. A system called T9 made texting possible with a small keyboard on the phone (Cardinal, 2011). BlackBerry innovated a featured keyboard which allows users to type as pushing a button of each number multiple times.

Modern technology is a new evolution of human civilization. It appears a new social stability in which efficiency is not optional any longer to consider, but an essentially enforced on all human activity (Giesler, 2006). The future will see greater applications of artificial intelligence (AI) in product design, and convergence as being together with computing, telecommunications, and media in a digital environment will be fundamental keys in human-computer interaction. The following summary addresses a history of the digital revolution for a major invention and development of digital technologies and machines that have converted computing and electronic technology from analog to a digital format. Data process in digital computing system has made significant changes to multi-media technology that transfers video and audio via a wireless network (Digital Revolution, n.d.). With the invention of the transistor in 1947, more advanced digital computers were made possible. Advancement in computer systems in the 50s and 60s were mainly made by the governments. As digital technology flourished in the 1970s, digital record keeping became the standard, and a new job was created, the data entry clerk. In 1984, only 8.2 percent of all U.S. households owned a computer according to the U.S. Census Bureau. By 1989, 15 percent of all U.S. households owned a computer. In the same period, businesses also became dependent on computers and digital technology. By 2000, 65 percent of the US households owned a computer.

Cell phones became as popular as computers by the early 2000s and also they were more advanced than previous phones. Phones in the 1990s were limited to making phone calls and simple games. However, text messaging was not common until the early 2000s. Digital revolution changed the way society communicate after mobile networking developed. In late 2005, the internet user population reached 1 billion, and 3 billion people used mobile phone worldwide. The rapid development of interconnectedness in mobile communication such as the internet, social media, website, apps, etc., has become a significant tool for standard digital communication.

2.2.2. Mobile Device Technology

A touch screen and mobile technology are other impacts to study as how digital interface has been changed to the recent graphical era. Until smartphone was introduced in 2007, a mobile phone was for only talking and text message. The first smartphones were not for the concept of old fashion- talking to someone. It introduced lots more functionality for personal, business, and entertainment. Today, smartphone means more than phone and people use it as a personal assistant (Myers, Nichols, Wobbrock, & Miller, 2004); buying products through online shopping, finding a location on the Google map, watching videos, sharing photos in social media and blogs, writing notes in the conference, checking and sending emails, monitoring health activity, and so on. As a modern society, culture and living life are changed with digital convention, designers and developers keep developing and inventing a new function and technology for high demands. Since 2000 that 3G networks were deployed, a mobile system has focused on the increasing speeds and worldwide access. Apple iPhone made it all possible beyond a mobile phone in 2007. With developed 4G technology for the internet application, smartphone and became a mobile desktop computer. Providing “Cloud” as synchronized data and information between each computer devices, a smartphone can be used in anywhere and anytime for simple desktop workloads.

Table II-4. A history of the mobile phone leading up to the modern smartphone (Smartphone Revolution)

1984	**1989**	**1992**	**1994**
			
Dyna TAC 8000X Motorola[12]	MicroTAC 8900X Motorola[13]	Nokia 1011[14]	IBM Simon[15]
1999	**1999**	**2000**	
			
Nokia 8210[16]	Blackberry 850[17]	Ericsson R320[18]	Blackberry 7230[19]

[12] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Motorola_DynaTAC
[13] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Motorola_MicroTAC#/media/File:Motorola_MicroTAC_9800x.jpg
[14] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Nokia_1011#/media/File:Nokia_1011.jpg
[15] Image retrieved from the public domain; https://en.wikipedia.org/wiki/IBM_Simon#/media/File:IBM_Simon_Personal_Communicator.png
[16] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Nokia_8210#/media/File:Nokia_8210_in_light_cover.jpg
[17] Image retrieved from the public domain; http://www.zdnet.com/pictures/a-history-of-blackberry-in-nine-iconic-handsets-and-one-meh-tablet-photos/
[18] Image retrieved from the public domain; http://www.gsmarena.com/ericsson_r320-pictures-194.php
[19] Image retrieved from the public domain; https://www.mobileemart.com/mobilepedia/blackberry/blackberry-7230.html

Table II-4. continued

2004	2007	2009	2011
			
Motorola razr v3i[20]	Apple iPhone 1st generation[21]	Motorola droid[22]	HTC HD7 (Window phone 7)[23]
2012	**2012**	**2014**	**2014**
			
Galaxy S3 Samsung[24]	Lumia 920 (Window phone 8) Nokia[25]	Galaxy S5 Samsung[26]	iPhone 6 Apple[27]

Table II-4 shows the history of the mobile phone features up to the smartphone in 2014. As significant changes of mobile phones with a touchscreen technology, analog keyboards and button have been disappeared. Many digital applications introduced a new interface comprised of icons as perceptive visual information. Ever since the first smartphone, Apple iPhone, presented the icon interface, other brands followed similar interface on screen layout, but its input interface system has not dramatically changed yet. Even though window phone introduced the same interface from the desktop, and many Android smartphone adopted it, many users tend to be satisfied with iPhone interface. However, a smartphone for mobile computing and communication needs to be reconfigured

[20] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Motorola_Razr#/media/File:RAZR_V3i_opened.JPG
[21] Image retrieved from the public domain; http://www.nerdeky.com/iphone
[22] Image retrieved from the public domain; https://en.wikipedia.org/wiki/Motorola_Droid#/media/File:Motorola-milestone-wikipedia.jpg
[23] Image retrieved from the public domain; http://www.worldtvpc.com/blog/wp-content/uploads/2010/10/htc-hd7-T-mobile.jpg
[24] Image retrieved from the public domain; http://www.gadgetgestures.com/verizon-offers-discounted-samsung-galaxy-s3/8344288
[25] Image retrieved from the public domain; http://i.i.cbsi.com/cnwk.1d/i/tim/2012/10/30/35471750-8.jpg
[26] Image retrieved from the public domain; http://techsmash.net/samsung-galaxy-s5-review-3/10463/
[27] Image retrieved from the public domain; http://www.gsmarena.com/apple_iphone_6-pictures-6378.php

for usability and user interface in the current and future mobile devices (Chen, Huang, Park & Yen, 2015). The article claimed "the new development of a simplicity construct and measurement scales; reduction, organization, component complexity, coordinative complexity, dynamic complexity, and visual aesthetics." Islam and Want (2014) addressed this evolution for six trends that are predicted for the strong influences of function and design for future smartphones *(Table II-5).* The future smartphone might be attached to a human body as being interactive with biometric chemistry. Wearable computing, "Google Glass" was also introduced by Google and other developers are still catching up with this new trend.

Table II-5. Six major trends affecting future smartphone design and use: Islam and Want (2014)

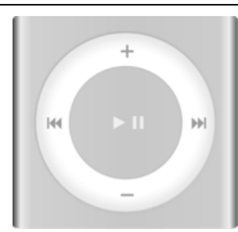
Trends	**Impact**
Personal Computing	*"Smartphone will become our primary computing platform and will dock with nearby displays and keyboards. They will become our computation, storage, and network hub."*
Internet of Things (IoT)	*"The smartphone will be the on-ramp for the IoT, letting you locate and interact with the world around you as easily as you currently search for information on the Internet."*
Multimedia delivery	*"The smartphone will rival more traditional platforms, such as the TV or desktop computer, for watching videos, and even storing libraries of multimedia content."*
Low power operation	*"The battery in smartphones will last longer, aided by new software structuring techniques and low power hardware accelerators."*
Wearable computing	*"The smartphone will be foldable and will take on unconventional shapes. It will merge into a diverse set of wearable technologies, from wrist-mounted devices to glasses and extensions of our clothing."*
Context awareness	*"Smartphone will be more context-aware and able to adapt to nearby people, places, and things."*

Apple introduced iPod as a portable digital MP3 format music player. A control user interface was designed with a central scroll wheel called "Apple Click Wheel." MP3 data compression provides a low-grade sound quality compared with music on a magnetic tape or compact disc. As the iPod having a thousand songs in a small device compared to a dozen on a tape cassette or CDs, users consider its functionality as be convenient instead of being superior. “Disruptive innovation” coined by Christensen refers to the function that provides inexpensive and convenient demand (Christensen and NetLibrary, 1997).

The iPod customers were very satisfied with its simplicity and elegance of product design. The significant notion of the iPod as the most dominate product compared with other competitors is a physical product design providing a fully integrated service and user interface. The iPod has developed digital interface based on digital content and navigation menu system. The iTunes allows users to manage their own music libraries on the iPod and their computers. Like Steve Jobs, Apple’s CEO, states “to put your entire music collection in your pocket and listen to it wherever you go” (Utterback and ebrary 2006). The concept of “The iPod economy” refers to “the iPod Design Chain” as putting it all together and optimizing the design to obtain the best performance. The iPod is not just for only playing music but can be used for the complex of software such as video, podcasting, and various accessories and partnerships in the App store.

The following *Table II-6* shows a history of the Apple iPod as each generation and lineup. The iPod in 2015 consist of three different types of devices for users; the ultra-compact iPod Shuffle, the compact iPod Nano and the touchscreen iPod Touch. The user interface of the iPod is unique to interact with users to create new and expanded usages. All iPod consist of five buttons and the main navigation, scroll wheel, is the most significant innovation that users can turn with a thumb or finger to control function. The center of the wheel is the same action like clicking a mouse. The scroll wheel provides different functions when it is in “Play Mode” and “Menu.” However, iPod touch identifies the same interface as iPhone. The product is not distinguished with iPhone looking so that the original identity.

Table II-6: History of iPod[28]

2001	2002	2003	2005
			
Classic 1st:	Classic 3rd:	Classic 4th:	Classic 5th:
2006	**2006**	**2007**	**2007**
			
Nano 2nd:	Shuffle 2nd:	Nano 3rd:	Touch 1st:
2009	**2010**	**2012**	**2015**
			
Nano 5th:	Shuffle 4th:	N Touch 5 th:	Touch 6 th:

2.3. Analog and Digital Interface

Analog is often associated with the old-school theory such as high-touch, face-to-face, personal and human as a communications approach. A response is directed from one to another through physical interaction. Sorman-Nisson (2013) illustrates a comparison between analog and digital in interactive communication *(Figure II-5)*. Digital interaction is faster than analog between users in terms of using high-tech and twenty-four hours available. The outcome of *Information and Communication Technologies* (ICTs; texting and instant

[28] All images retrieved from the public domain; https://en.wikipedia.org/wiki/IPod

messaging) in digital devices limits delivery of self-expression and engagement between users rather than a conversation in the face-to-face condition (Ranney and Troop-Gordon, 2015).

Analogue	Digital
Hearts	Minds
Face to face	Interface to interface
Facial recognition	Facebook recognition
High-touch	High-tech
Old school	New school
Personal touch	Digital connect
Nine to five	24/7/365
Slow	Fast
Word-of-mouth	Word-of-mouse
Offline	Online

Figure II-5. Analog versus Digital in Interaction (Sorman-Nilsson, Anders. Digilogue : How to Win the Digital Minds and Analogue Hearts of Tomorrow's Customer. Somerset, NJ, USA: John Wiley & Sons, 2013)

An analog interface appears to control and operation tasks as perceptive information since the industrial revolution began. Even though Bauhaus principles, "Form follows function," in earlier 20th century started to reflect industrial design theory, digital interface design does not seem to follow this theory effectively (Interaction Design Foundation, n.d.). The transition to the digital age has brought an enormous advantage of user experiences for personal and professional business. Digital devices enable users communicate with others in non-verbal talk such as text message and e-mail communication. As a new interactive communication through digital devices such as smartphone and computer, the digital interface became Graphic User Interface in a navigation system. Seel (2012) refers to digital devices like improving our access to knowledge, not as making people wise yet. User experience (UX) in the digital interface has improved functional literacy for users, but critical literacy is still lacking in terms of heavy relying on the digital information in modern society.

2.3.1. Definition

As dictionary definition of “Analog” addresses using signals or information conferred by a continuously variable physical quality such as spatial position or voltage (A Dictionary of information acronyms, n.d.). The definition of “Digital” is signals or data articulated as series of the digits 0 and 1, typically represented by values of physical quality as voltage or magnetic polarization (Digital - definition of digital in English from the Oxford, n.d.). Sorman-Nisson (2013) defines its definition as visual diagram by using an example of the watch. Analog’s information appears other physical condition such as position, spatial, visual orientation from the watch. For instance, users may perceive correct information without additional visual information (number) as long as they wear the watch the right way. In the *Figure II-6*, the time can be 9 o’clock if it is in an incorrect way. However, a digital watch indicates visual information precisely without any condition of a watch. A User is aware of incorrect information from attempting to read the digit numbers.

Figure II-6. Analogue versus digital clock (Sorman-Nilsson, Anders 2013)

The definition between analog and digital is distinguished by a signal. Analog appears continuous signal for the time varying feature, and digital is based on discontinuing values represented by numbers (0, 1) or letter, sounds, images, and other measurements of the digital system (*Figure II-7*).

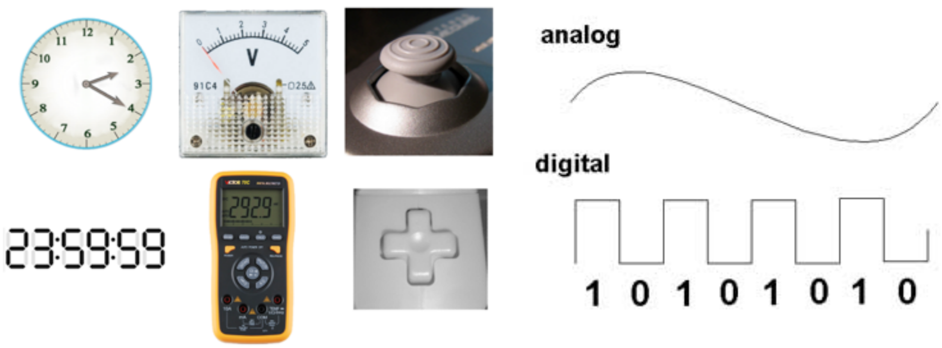


Figure II-7. Analogue versus digital signal

2.3.2 Being Analog in Hardware and Digital in Software

Analog formula appears user-centered design for one way-driven, affordable, and low-tech approaches. An analog device or machine is slower than digital computer system in a way that users complete a task by limited physical interaction, but it allows users to active more by critical thinking process. For instance, using a digital typewriting software in computer devices is much faster and accurate than using an old typewriter. However, old typewriter requires users to have knowledge of spelling a word correctly. In terms of digital technology condition that providing automatic spell and grammar check, education in a digital generation appears a lack of learning ability in terms of missing significant practices in learning behaviors. Even though we appreciate high-tech digitalization as ease of use and efficiency of every-day-products, education should be not ignored by conservative role and reasonability for using technologies in a correct method (Vlieghe, 2014).

Human is analog creatures. People interact with digital media by human senses (sight, hearing and touch) as physical condition (Seel, 2012). For instance, tracking device such as mouse and buttons in touchscreen allows users to point and click on desired contents on the computer screen. “Being Digital” written by Negroponte was a significant key point to rethink about a relationship between analog physics and digital technology. This book analyzes the pros and cons of the technologies to predict how modern technology would be changed in terms of different communication methods. Since the book was published in 1995, all the Negroponte prediction of the future technologies moving toward being digitalized has become real in our life. All tangible physical objects are made up of atoms, and digital information is made of bits (Negroponte, 1995). He believes that all physical form of analog information that is now made of atoms such as books, CDs, Phone, pencil, etc. will eventually be made into bits. This prediction has arrived at a new media culture reflected technological interface as touchscreen and voice recognition through digital devices that we use every day now. However, his concerns that being digital are not opposite by analog concept. Being digital is an innovated convergence of technology relationship between hardware and software.

A digital era has changed human being with culture, society, and environment in twenty century. People see someone talking with no one in walking is not a strange any longer. People communicate text, email, and social media instead of face-to-face. Online shopping becomes a huge commercial business to enable users to find the best options for price, quality, and value of a product through other users' reviews. Most people in a subway are looking at smartphone instead of books or newspaper. Visiting a new place through Google Earth is free, convenient and less time-consuming. Checking out e-books on a personal computer instead of visiting a library enables students saving much time. Using a credit card creates new business influences such as bounces of reward cash back or other credits. Users now control home appliances remotely. People are living under the control of digital services.

The Digital technology has changed the concept of individual or personal as "being alone." Users spend many hours for digital devices such as checking email, surfing the internet, sending a text message and watching social media. Since iPhone introduced a touch screen and multi-smart app functions, users became fractionated about a digital interface with icons and menus. Even most users were able to understand how to use it without manual instructions in terms of the prior user experiences of using a personal computer.

2.3.3 Analysis of Effectiveness in User Interface Design

A development of telephone system is a most predominant model to compare with user interface between analog and digital technology. For decades, all calls had been operated by a human operator, who could also listen in on someone's call. Dial phone were not introduced until 1919, and it was not until the 1950s-80 years after the phone was invented that direct distance dialing (DDD) allowed callers to dial long-distance without the help of an operator. The last manual phones were not phased out until the 1970s-almost a hundred years after they were introduced.

Table II-7. Features of telephone interface

	Function	**Interface**	**Interaction**
Radial dialing phone	- Verbal communication - Caller and receiver - Sound	- Dial (Physical) - Number (Visual) - Receiver handle (Physical) - Unit device (wire)	- Two Hands - one finger
Digital home and office phone	- Verbal communication - Caller and receiver(s) - Voice message - Caller ID - Perception of letter form - Sound and Visual indication	- Button (Physical) - Mono screen (Visual) - Number (Physical & Visual) - Main unite device (Physical & Visual) - Phone device (Cordless & wire) - Speaker (Audio)	- One or two Hands - Finger(s)

Table II-7. continued

Smartphone	- All telecommunication system from the digital phone - Text message - Video/audio call - Apps - Internet - Camera - Music player	- Button (Physical & digital) - Color Screen (Visual) - Icon (Visual) - Phone device (wireless) - Speaker (Audio) - Voice Command (Audio)	- One or two Hands - Finger(s) - Voice

While an analog phone provides users only voice transmitted over the phone, a digital phone allows users engage with other users in conversation. An analog phone focuses on voice command for the only verbal communication between two users; this means that interaction is more likely analog approach restricted in limited functionality. A digital phone provides users more functionality beyond verbal communication between users such as recording a greeting message, checking a voice message from the caller, storage of contacts and other intercommunication functions *(Table II-7).* This digital technology makes “interactive communication” happened since the cordless telephone was invented by Teri Pall in 1965. However, digital phone still focused on fundamental telecommunication functionality for users; a smartphone has changed the users’ environment, behavior, society, and culture.

2.3.4 Digilog Design

The philosophical theory of “Digilog” designs has introduced innovated concepts with characteristic interpretation as a new technology, retro emotion, sustainability and influences appearing convergence of effective function between analog and digital. Digilog concept not only creates new affordance theory that users interact with products for understanding how to use easily and perceiving visual form as more comfortable but also discovers a new technology assisting a human interaction with devices and machines in product design. *Figure II-13* is an example of fundamental Digilog concept that is simply identified with each analog and digital characteristic. “Digilog Clock” created by Masayoshi Suzuki of Pinto where the analog hand shows the minutes, and the digital number displayed at the top shows the hour (Pinto, n.d.). The other example is the “Time Switch” created by Harc Lee that a simple flick of the switch could turn on or off the numerical, backlit display (Time Switch Wall Clock Is Perfect For Proctastinators With Great Imaginations, 2009). Both products specify digital and analog function visible and understandable what it tells users. It realizes both readability and silent presence. While most dialog concept appears in product design, however, there are not case studies or products introducing user interface (UI) and user experience design (UX) yet.

FigureII-8. Fundamental “Digilog” concept (left: Digilog Clock, right: Time Switch)[29]

The Digilog is a new word combined with its definition between analog and digital. However, Digilog has developed connotative definition and classification through the digital world. *“Digital minds and analog hearts.”* Sorman-Nilsson describes the Digilog as a convergence of analog and digital. His book, *“Digilog,”* addresses significant concerns of analog and digital as being separated and combined with many different circumstances. These two words not only appears big contrast of its origin meaning, but also it becomes a good harmony through various models: society, culture, and an environment in a human being. *Figure II-9* illustrates a relationship between analog and digital united by

[29] Images retrieved from http://www.iainclaridge.co.uk/blog/852

"adaptation." The Digilog is what enables a user experience value to digital minds, and enables a user connect with analog hearts.

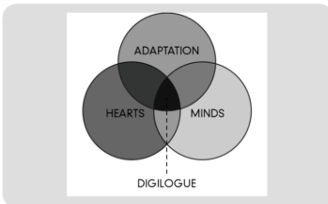


Figure II-9. Digilog-The convergence of the digital and the analog (Sorman-Nilsson, Anders 2013)

A New Technology

With the advancement and digital technology, our lives are changing rapidly and becoming more convenient and with this new technology that combines primary tool of communication in the analog era. Digilog concept has influenced many engineers and designers to develop hardware and software for many existing products. A predominant digilog concept is appeared with Augmented Reality (AR) as a new technology for children learning. Modern age children as "Bone Digital" have many problems from lack of concentration, impulsive behavior, and social participation caused by digital computer devices (Kim 2010). Approaching digilog interaction as 'playing' provides children to learn sociality, emotions, reasoning, and personal relationships (Kim and Choi 2010). Moreover, children are provided the opportunity for learning the ability of empathy by interactive reading experiences through the augmented reality (AR) technology. *"Children in the AR condition (Figure II-10) were more actively involved in role-playing and showed less unrelated perspectives than children in other digital game environment"* (Gil at el., 2014).

Figure II-10. A child experiencing AR Petite Theater and his view through HMO (Kim 2010)

However, Digilog hardware products have also introduced advantage of each digital software and analog hardware. This interactive convergence provides users to remain of inherent behavior for executing tasks as the way it supposed to be. *Figure II-11* is a product called "Linking" made by Wacom. The 'Linking' allows users draw on any paper with a digital pen, which interacts with a receiver clipped to the edge of standard paper or sketchbooks. The completed sketches transfer the digital files showing in the Inkling Sketch Manager software to edit, delete or add layers as well as to change formats. This technology reduced the step of producing a digital transformation that is typically occurred by a scanner.

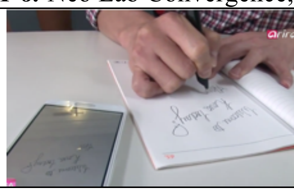
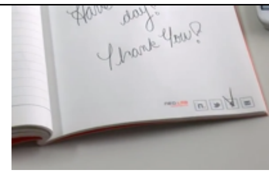
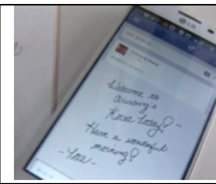
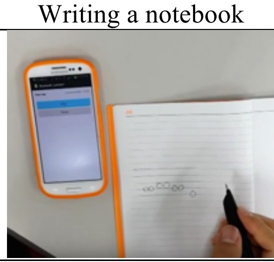
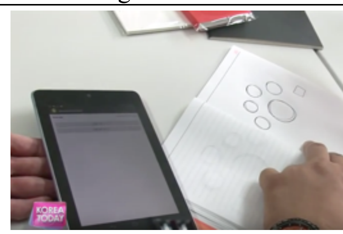
Figure II-11. Wacom digital pen, "Linking"[30]

A pencil and paper in another example, Steve S. Lee, CEO in Neo LAB Convergence, introduced more advanced technology, "Neo Smartpen N2", which contents transfer to the smartphone screen next (Korea Today, n.d.). Table 7 shows two tasks transferring writing a

[30] Images retrieved from http://www.ohgizmo.com/2011/08/30/wacom-inkling-digital-sketch-pen

note and playing music. Users can use a content written on paper in various ways so that the analog contents interact with digital media such as image and sound. This technology underlines effective Digilog convergence as how analog and digital together provides users better interaction in consideration of digital to be responded fast, and analog to be personal touch basis.

Table II-8. Neo Lab Convergence, "Neo Smartpen N2"[31]

		
Writing a notebook	Positing on the Facebook	Competed post
		
Music notes playing	Music instrument playing	Playing a drum with touch

Another example of Digilog concept introduced the BeoSound 5 System (*Figure II-12*) for music fans who is enthusiastic about an intelligent 'music identity' system similar to Pandora.com's and Microsoft's MixView ($6,000 Bang & Olufsen System Features Pandora-like Music Analysis, n.d.). The control interface appears an aluminum radial wheel that the UI identifies interactive digital presentation in the control panel. Even though this device provides 10.4-inch digital LCD screen, the UI is different from other visual controls such as tablet PC with touch screen control.

[31] Images captured from "Arirang Issue," https://www.youtube.com/watch?v=cyQ8EJx5L5U

Figure II-12. BeoSound 5 System[32]

Retro Emotion

The word, "Retro" and "Vintage," has been in the headlines of the professional press as the importance of the retro-phenomenon. Retro concept development in design fields has increased attention to consumer's individual responses in product design semantics (Veryzer, 1993; Yalch and Brunel, 1996; Dell'Era et al., 2009). Retro products appear a visual combination from the past with updated new performance and function (Brown, 1999, 2001; Brown et al., 2003). Brown and colleagues have addressed that the retro-marketing phenomenon occurs to consumers' propensity towards nostalgia needs through the use of significant design features from the past.

The *Table II-9* introduces design concept of the retro product appearing its form and function based on Digilog approaches; talking on the "Smartphone desk set" lets users comfort instead of holding with hands (Native Union POP Desk V2, Pop Phone with Metal Stand, n.d.). The design concept underpins that many smartphone users may have painful and discomfort for holding a smartphone in a long conversation. The concept of the traditional physics also allows users have fun and play in an inexpensive way that the "iPhone horn" amplifies the sound from the built-in speaker of iPhone. It does not require any external power source or batteries to use (Top 10: Cool gadget accessories, n.d.). Retro design

[32] Image retrieved from http://www.ecoustics.com/products/bang-olufsen-beosound-5-digital/

approaches emotional acceptance through visual information such as form, color, texture and dimension (LG TV 32LN630R, USB Drive, LG Smartphone). The LG Quick Circle case, which has a window to let users view notifications while the cover is closed, also appears to be making a return to the G4 (LG's leather-clad G4 revealed in leaked images, 2015). The images show what appear to be a multitude of swappable back plates: six different real leatherbacks (ranging from black and brown to baby blue and yellow), as well as three more traditional plastic backs. It is fair to assume that the leather versions will carry a cost premium.

Table II-9. Digilog product design[33]

		
Smartphone Desk Set	The iPhone Horn	LG TV 32LN630R
		
USB Drive	LG Smartphone G4	Apple Mac Concept Design

Another trend of the retro design appears renovated concept. Apple Mac computer as possible future concept design shows the same style as an old Mac computer. It is a combination of Apple's current and former identity of the product lines. A "retro-innovation"

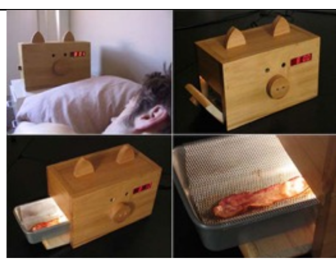
[33] LG TV 32LN630R: Image retrieved from https://www.amazon.com/LG-32LN630R-Classic-Television-Display/dp/B00IE3B9SW
Smartphone Desk Set: Image retrieved from http://techtake.net/wp-content/uploads/2013/09/popdesk2.png
The iPhone Horn: Image retrieved from http://techtake.net/wp-content/uploads/2013/10/eForCityhorniphonespeaker6.jpg
USB Drive: Image retrieved from http://www.dibrary.net/posts/list/1/470/66702/0.do
LG Smartphone G4: Image retrieved from http://www.ibtimes.co.uk/lg-g4-lg-launches-leather-clad-flagship-slr-quality-camera-1498787#slideshow/1435704
Apple Mac Concept Design: Image retrieved from http://www.designboom.com/technology/curvedlabs-mac-design-apple-macintosh-01-14-2015/

trend is emerging, and new goods and services are designed to connect users with the past in ways that are both nostalgic and interactive. Retro-innovation expresses a desire to reconnect with something essential that appears to be missing from our modern lives.

Sustainability and Influence

Digilog design concept has influenced many new design products for sustainability. Applying digital technology to the products that require essential functionality. The *table II-10* introduces a few products for making users aware of what they intend to do. Waking up early morning is difficult, but people are not conscious of the plan they have made for the next morning. However, these products from the Digilog concept create a user's motivation for the goal of using a product. The "Bacon alarm clock" stimulates the sense of smell for users to wake up on the bed. It is already been featured on such sites as Wired, American Public Media's "Splendid Table", Engadget, Ubergizmo, Gear Live, Design Boom, and many more (Wake'n Bacon, 2011).

Table II-10. Digilog - Alarm Clock[34]

		
Bacon alarm clock	Shredder alarm clock	Shape Up alarm clock dumbbell

The phrase, "You snooze, You loose" is clever nonetheless for the shredder alarm clock. If users do not get up when the alarm sounds, it is going to cost them. From the image

[34] Bacon alarm clock: Image retrieved from http://www.thisiswhyimbroke.com/bacon-alarm-clock
Shredder alarm clock: Image retrieved from http://mashable.com/2011/05/29/money-shredding-alarm/#pyASOQKyHsq5
Shape Up alarm clock dumbbell: Image retrieved from http://www.thisiswhyimbroke.com/dumbbell-alarm-clock

on the table, that shredder does a thorough job of destroying currency or whatever else users would like to place on it (Money-Shredding Alarm Clock Is Completely Unforgiving, n.d.). The last image is a product called, “Shape Up alarm clock dumbbell,” which will not stop alarm sound until users complete 30 reps (Shape Up Alarm Clock Dumbbell to wake masochists, n.d.).

All these products address significant concerns about user interaction of the product function. Users’ demands and desires are reflected in the product that requires digilog interaction between digital function and analog actives. Essential functionality from either digital interface or analog mechanism needs to be considered as human computer interaction (HCI) in ways that users can sustain for executing their activities.

2.4. User Interface Design

Interfaces are designed with specific purposes for user oriented such as reading, seeing, listening, communication and experiences (Anderson and Pold 2011). User Interface design (UI) is based on the design system of operating machines and software focusing on the user experience (Kshama Solution, 2015). An interface design refers to what people see, hear, or feel, and it is a part of interaction design that users experience. An interface is also about how people can engage with a product and how that product responds. Thus, the interface needs to be visible, accessible and interactive (Saffer 2007). The user interface (UI) design aims to enable the user interact with computer and machine as simple and efficient as possible to accomplish the user goals (User Experience Basics, n.d.). For instance, perceiving the shape of a hammer looks the way it is functioning because of its shape as being optimal for driving in nails. However, form in digital devices does not follow function. Objects on a screen can have any shape and can potentially serve any purpose. The range of interface requires the need of different technologies and uses. The early concept of the interface was in regards to understanding as how human and a computer could communicate with the software and hardware (Hackos and Redish, 1998). Control is the final product of interface, and its input system enables human communicate with software and hardware. This concept has evolved the cognitive and emotional aspects of the user's experience. Peter Morville (2004) describes as how information should accommodate users for the valuable and meaningful user experiences.

- *"Useful: Content should be original and fulfill a need"*
- *"Usable: Site must be easy to use"*
- *"Desirable: Image, identity, brand, and other design elements are used to evoke emotion and appreciation"*
- *"Findable: Content needs to be navigable and locatable onsite and offsite"*
- *"Accessible: Content needs to be accessible to people with disabilities"*
- *"Credible: Users must trust and believe what you tell them"*

However, the interface is not just as technology. Hookway (2014) defines the interface as at once ubiquitous and hidden view. He considers the interface as a form of relation with technology more than two entities, conditions, or states between human and machine. According to his notion of the word "interface," "between face" refers to activities within limited space, and "a facing between" accounts extending boundary or zone. Therefore, the interface is a combination of bounding entities and a means of accessing, confronting, or projecting into an exteriority.

"Interaction design is an interdisciplinary action between industrial and communication design, human factors, and human-computer interaction" (Saffer, 2007). The

interaction takes place between people, machine, and a variety of combination units. People interact with every product and digital media through everyday life; talking on the phone, sending an email, making a toast, brewing coffee, driving a car, listening to music on an MP3 player, watching on TV, and so forth. All of these things are made possible by technology development. Interaction design makes all these activities useful, usable and fun. Even though people are a delight to all good interaction designs day by day, there are still many infrastructures appearing poor interaction design all around us. User interaction is anytime behavior that should be considered by interaction designers knowing about how a product works (Saffer, 2007). Bill Moggridge called “Interaction design” as the new practice of “designing” by different designers from engineering, communication and product design. Even though all design activities appear different tasks and experiments, it shows as one product that interacts with users (Moggridge, 2007).

The formal discipline of interaction design has been around for less than twenty years (Saffer, 2009). Since the era of ubiquitous computing, user interfaces have been formed many different ways to interact with users. The relationships of interaction have expanded various disciplines such as industrial design (ID), graphic design, user experience (UX) design and human factors. Overlapped disciplines are separated, but these all disciplines should be working in a harmony to make a useful product that provides users the efficient interaction through physical and invisible interactive communication. Saffer (2009) introduced the elements of interaction design (motion, space, time, appearance, texture and sound), and the laws (Fitt’s, Hick’s, the Poka-Yoke Principle, feedback, and feed-forward, and direct and indirect manipulation. Products and services as being digital, analog or both features are getting more conceptual with the elements in interaction design.

2.4.1. Graphic User Interface (GUI)

User Interface Design appears different interactive forms in terms of the mobile access ability and capability. The visual appearance of products reflects informative function interpreted, approached and used to improve studying how users respond to the visual form of products (Crilly, Moultrie, and Clarkson, 2009). However, the designers' role in organizing products function of interface design has been relatively neglected (Sener and Wormald, 2008). Punch cards are one of the first interfaces with computers for data storage. Almost all of them were eliminated by command-line or GUI interfaces in the 1980s. Entering any data or information into the computer required days of plugging in cables or machines, and hours preparing a statement on punch cards or paper tape for the machine to read.

Table II-11 summarizes the past four decades of user interface evolution. As input control such as "button," "click", "type" action has been counted until the new interface has evolved more high-tech sensory beyond using only fingers or hands. However, many researchers and developers consider this interaction to engage with users as being affordable and user-friendly. Siewiorek (2002) addresses significant human environment, which requires a new interface to wearable and context-aware computers. The quote, "The wearable computer should offer seamless integration of information processing tools with the existing work environment," directs the new functionality of the user interaction in a natural and unobtrusive manner instead of the conventional methods of interaction such as with keyboard, mouse, joystick, and monitor in a physical relationship between users and devices.

Table II-11. User interface revolution: Siewiorek (2002)

Year	**Input/Output/Information**
1970	Keyboard, Alphanumeric display, text
1985	Keyboard/mouse, graphics display, icons
2000	Handwriting/Speed recognition, speed synthesis, multimodal
2015	Position sensing/eye tracking, stereo audio/video, 3D virtual reality

2.4.2. Gesture based Interaction Design

In interaction design, gestures are defined as *"…any physical movement that a digital system can sense and respond to without the aid of a traditional pointing device such as a mouse or stylus"* (Saffer 2008). People have learned various gestures based interaction through the touchscreen on the smartphone, tablet PC, video game and public kiosks systems such as ATMs, airline check-in, and wayfinding map in a shopping mall. This new era requires more than traditional skill set and techniques in ways users need experiences of knowing how to control and interact with all new devices introducing a new interface. Users confront a significant challenge to understanding a stem of the interactive process when a new device provides a lack of clue with only one or two buttons. It happened when iPhone introduced a new interface in 2007. When Jeff Han showed the demo with a big screen controlled by figures at 2006 TED conference, it was likely "dream comes true" that is much closer to be with the move, Minority Report (2002). Over eight years of a short history of a new interactive touch screen interface technology, gestures by fingers to conduct tasks on the screen are not any more specific knowledge or lessons required.

The invention of touch sensors, wireless controllers, and motion track created new gestural interaction through a human body such as waving hands, nodding head, touching the screen with a figure, moving eyeball and brow. The action, "Tapping" became the new click in entering a new era of interaction design. Gestural interfaces provide a variety of physical actions from the whole body for triggering system behaviors. Traditional conventions of computer interaction, especially using a mouse for moving to the target objects to click has been replaced input action with a figure gesture in mobile devices. A new digital technology appears direct and indirect interaction with a digital interface. Direct manipulation coined by Ben Shneiderman (1983) is *"the ability to manipulate digital objects on a screen without the use of command-line commands."* Direct input requires that users touch the device directly to control input actions and manipulations such as using mice and joysticks even touch screen devices. Indirect input is controlled by sensors that detect a human body's input gestures; gestural hands and figure, movement of the whole body, and eyeball tracking. *Table II-12* introduces examples that describe a different gestural input action between direct and indirect interaction. The Clapper turns on and off the electrical flow of any products plugged into the Clapper. Indirect control action by a physical gesture allows users to interact with operating and controlling products through the sensor.

Table II-12. Direct and indirect interaction[35]

Direct Interaction	**Indirect Interaction**
	
A Computer Mouse	The Clapper
	
Joystick control for Smartphone (iPEGA)	Water Faucet

[35] A Computer Mouse: Image retrieved from http://www.frameusa.com/blog/online-shopping-keeping-it-safe-fun-and-easy/
Joystick control for Smartphone (iPEGA): Image retrieved from http://m.dhgate.com/product/ab14736-ipega-9033-pg-9033-wireless-bluetooth/375022464.html
Water Faucet: Image retrieved from https://www.sloan.com/commercial-bathroom-products/automatic-sink-faucets/deck-mounted

A good product should be “intuitive” or “innovative.” A good gestural interface appears with characteristics as “useful, usable and desirable” (Sanders, 1992). Saffer (2007) addresses the characteristics of good gestural interface that Gestural interface should be; discoverable for users to perceive products as how to interact with objects; responsive as how users get some feedback of their action; appropriate to the culture, situation, and context; smart and clever to provide what users can’t easily do alone. Most gestural interface refers to physical motion and movement that interacts with only one major function or task path. Simple gestures such as taps, swipes, and waves are essential tasks for most natural human behaviors in which Japanese product designer, Naoto Fukasawa, claimed that the best designs are those that dissolve in behavior (Jane 2006). This means that the product themselves disappears into whatever the user is doing. Most natural designs provide matched behaviors to the gesture humans that enables that behavior.

2.4.3. Analysis of Input Control Interface Design

A control interface needs to provide users the affordance in its appearance that users understand what the product is capable of and the power to realize that capability (Saffer 2007). Most applications and devices have some perceptible controls to operate the features of the product. For instance, a dial to control volume on a stereo or slider to select a date arrange is a physical visualization of control information. Most analog control system appears affordable visual information, in which users perceive its form as knowing how to use. For example, a light switch (*Figure II-13*) is a very simple control addressing only two ways in control task. It changes one setting (on) to another (off) and it does not change the physical condition there until changed. A switch knob is shaped as a holder with finger(s) to drive it between on and off setting. It is very much simple and affordable to perceive its form as perceptive design in physical condition. Even though its form presents differently as consuming product values*; high and low value, big and small size, and vertical and horizontal format*, a fundamental functionality is suited to the basic meaning of the change control.

Figure II-13. A standard form of a light switch (Wire 3 Way Light Switch - Electricians)[36]

As the earlier discussion in this chapter, however, an interface design in many digital devices does not seem to be appeared in affordance rules. *Table II-13* shows three different power switch control buttons in digital devices. The first image is a universal icon of "Power" as a denotative symbol. It is a basis of touching it with a finger or clicking it with a mouse. For the second and third GUI, users may conduct an action based on their affordable perception or prior experiences and digital software allows users enable to switch the button by both "click" and "slide." In compared to the analog switch control, the action "slide" action is evidently different from the action "push" by a finger. Thus, an affordable action for using a power switch is commonly "slide" in digital media.

Table II-13. A standard GUI form of power switch in digital

		
Single Power Button	Digital Switch with text in	Digital Switch with text out

[36] Left image retrieved from http://gettingtorx.com/2015/01/19/is-your-switch-on-or-off-beast-mode-digging-deep-additional-effort/
Right image retrieved from http://www.talklocal.com/blog/2013/06/s/electricians/wire-3-way-light-switch/

Table II-14. Analysis of comparison between analog and digital control interface

	Adjustment tasks	Category	Control	Visual Interface Control	
				Analog	Digital
1	Scale/Size	Computer Screen	Zoom in/out (Screen/text/graphic Size)	Keyboard Control	Icons/ touch
		GPS (Car)	Zoom in/out (Screen/text/graphic Size)	Control button	Icons/ touch
		Tablet PC/Smartphone	Big/Small (Screen/text/graphic Size)	None	Icons/ touch
		Camera	Zoom in/out (Distance)	Control button	Icons/ touch
2	Time	Alarm Timer	Duration	Control button	Icons/ touch
		Motion Detector	On/Off	Power button	N/A
		Tempo meter	Fast/Slow	Measurement tap	Icons/ touch
3	Brightness/Color	Computer Devices	Bright/dark/color/saturation	Keyboard Control	Icons/ touch
		Lamp/Light	Dim	Knob	Icons/ touch
		Lights (LED)	Colors/Dim	Control button	Icons/ touch
5	Volume	Speaker	Loud/quiet/mute	Knob/Button	Icons/ touch
		Audio System	Bass/Mid/High sound	Knob/Button	Icons/ touch
6	Movement	Video Game	Up/down/left/right	Joystick/Button	N/A
		Drone	Up/don/left/right/rotate	Joystick/Button	Icons/ touch
		Smartphone Game	Up/don/left/right/rotate	N/A	Icons/ touch
7	Select	TV	Up/Down (Channel)	Button	Icons/ touch
		DVD/VCR/CD	Forward/reward (Track)	Button	N/A
		Digital Newspaper	Fold/turn over (Page)	N/A	Button
		Online Booking	Date/location/Price	N/A	Icons/ touch
8	Temperature	Thermostat	Warm/cold	Button/Knob	Icons/ touch
9	Strength	Fan	Slow/Fast	Button/Knob	N/A
		Air Unit (Car)	Weak/Strong	Button/Knob	N/A
		Hair Dryer	Weak/Strong	Switch button	N/A
		Massage Machine	Soft/Harder	Switch button	N/A
		Vacuum	Weak/Strong	Switch button	N/A
		Video Game (Nintendo)	Strong/Mild/Weak	Control device	N/A
10	Amount	Printer/Copy machine	Pages	Button	Icons/ touch
		Computer Screen	Pixel/Resolution	N/A	Icons
		Coffee Machine	Cup	Button	Icons/ touch
11	Height	Chair	Up/down/lean	Knob	Button
12	Balance	Level App	Up/down/tilt	N/A	Icons/ touch Device move
		Audio	Left/right (Sound)	Knob	Icons/ touch

However, an interface in both analog and digital devices or machines appears mutual arrangement; button, linear and radial. Users have experiences with different control actions based on the type of the products, hardware and software, and presentation methods. These three type of control interface is not yet clear to define how effective, useful, easier to control tasks between analog and digital interface. This investigation and analysis lead to study findings how users interact better in a case of tasks, media, and behavior observation. *Table II-14* is an analysis of the comparison between analog and digital control interface categorized in adjustment tasks. The adjustment tasks are comprised of physical and visual interaction that can be also distinguished with a digital and analog interface in user experiences. Most products and machines provide users a button and knob in an analog interface, in which users' action in input control requires diverse interaction such as "click," "type," and "hold" by finger(s) and hands. Digital device provides application and software in which users interacts with menu or icon as graphic information. Digital touch screen such as smartphone, tablet PC, and public kiosk screen is based on the responding of the touch sensor that is received as a finger gesture in user interaction.

Button

Buttons are the most common control in human-computer interaction. Once users begin to look for computer devices and product machines, it is apparent that buttons are everywhere, all over our interfaces. A button is used for direct-input and adjustment control, for instance, turning TV on/off, adjusting a volume and changing a channel. People interact with buttons most every day such as home appliances, using a computer and office phone at work, and driving a car. Even a smartphone we use every day comprises more than 50 buttons for operating various functionalities. A button appears a single shape that describes its functionality for users to understand 'Affordable action' such as pushing the physical form or touching the icon on the touchscreen. Power buttons in analog typically appear three different control actions: switching on/off as different positions, pushing a single button to switch on/off and selecting each button for on/off. Even though all input control in digital is provided as graphic icons, the power control for "On" is still controlled by an analog button, for instance, smartphone and computer.

Buttons is comprised of many different shapes, colors and size. These physical appearances are significant for usability principles such as efficiency, learnability, and memorability. *Figure II-14* introduces various remote controls that users confront everyday usages. Each remote control provides common shapes and colors in a group that users may recognize different functionality to control devices. As a cable TV provides more than 100 channels and various options, a remote control is apparently similar with operating a computer software; watching a demand movie, searching TV guides, recording a show while users are watching another channel, changing a TV mode and setting, etc. All examples of the remote controls in figure appear different interface design even though most functions are common among the cable TV service. More than 30 buttons in a remote control based on directed-action may be not easy to perceive it as being familiar with, even though users prefer to use simple action and control everyday. However, some options which are not often used may be a big challenge for them to understand what-to-do action.

Figure II-14. Shapes & Colors in Group

While an analog interface introduces a simple and easy button control, more numbers of the button in products give a difficulty of interaction to users. However, even though a smartphone typically provides more than 50 button icons, a smartphone interface is less complicated than interface with 30 buttons in a remote control. The reason for this phenomenon is because a digital interface is designed by examining usability with the relationship between visual cognition and contextual response carefully. Pete Orme addresses principles for successful button design in UI and UX design. It is important that graphic buttons match with contextual style to the interface by using appropriate shapes, size, effects, colors, textures and texts/fonts.

In digital devices such as computers and smartphones, unlimited Graphic User Interface (GUI) also need to examine an affordance theory more carefully. While analog button provides directed-action, which is the action of pressing a button moving to the task as, what a user expects, digital button includes more than an origin action. *Figure II-15* appears same shape and color. However, an arrow directs input action differently based on the orientation of the arrow. An arrow pointing right gives the user some sense of moving on or leaving the page, but an arrow pointing down implies that certain content will be progressively revealed below, or sub-menu will open (drop-down).

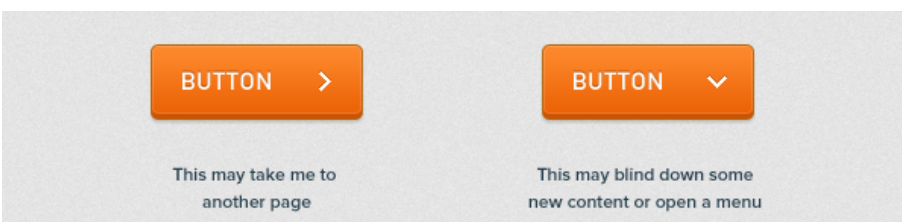


Figure II-15. GUI Affordance[37]

Linear

A linear controller typically appears horizontal and vertical interface as an adjustment control. It is not common to find this controller in an analog system but any particular devices such as a mixed controller in a broadcasting and electronic music instrument still

[37] Image retrieved from http://webdesign.tutsplus.com/articles/principles-for-successful-button-design--webdesign-6094

accommodate its interface system. The advantage of linear control is to adjust the sequencing changes. For mixing various input values in a control panel, the linear control system allows users to have sequencing experiences with tweaking, mortifying and mixing physical values (*Figure II-16*).

Figure II-16. Yamaha Motif XS (Guide to Control Surfaces)[38]

Since mechanic technology has developed with a digital computing system, linear controller in a car has disappeared in the early 1990s (*Table II-15*). Linear controller was used for adjusting an air temperature and changing air circulation. Drivers adjusted a comfortable level between one to the other side of the controller, and they perceived only warm and cool visualization as icon or infographic. This functionality has been improved with a digital control system providing drivers for setting a comfortable level of air temperature. However, while a linear control has disappeared in analog, digital media and devices have implied its concept into various adjustment control system.

Table II-15. Car dashboard (Vehicle Audio)[39]

	
1958 FORD Taunus 17M P2 deLuxe	1990 Ford Sierra CLX

[38] Image retrieved from http://happyharry.net/yamaha/motifxs/photos/
[39] Image retrieved from https://commons.wikimedia.org/wiki/File:FORD_Taunus_17M_P2(TL)_deLuxe_Two_door_1958_Radio_Blaupunkt_Köln.jpg

It is common that computer devices allow users to adjust various setting with a linear controller. Controllers appear a small icon to drag it to left and right or up and down. *Table II-16* shows different adjustment control that describes an interface with text or graphic information. Users respond to drag into the value that they desire, but the segment between each control does not provide continue sequence adjustment. The color control in Adobe Photoshop, however, detects more detail accuracy with input numbers. This fact underpins that a linear control in digital and analog is more effective and efficient when users need to deal with control a complex frequency and variable values.

Table II-16. Adjustment control in PC.

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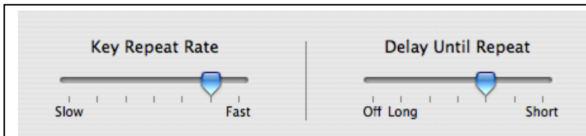
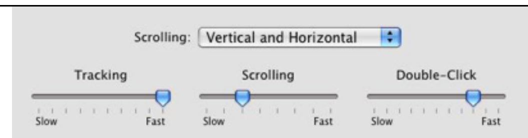
<tr><td>
</td><td>
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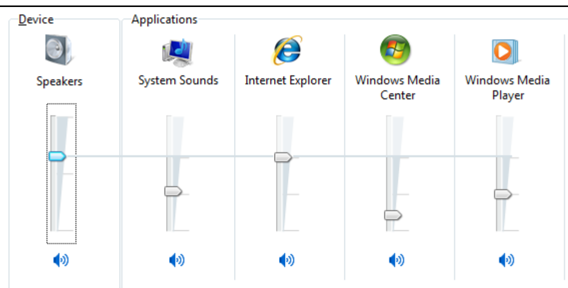
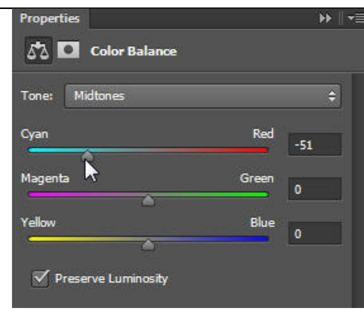
<tr><td>
</td><td>
</td></tr>
<tr><td>Window Audio Control</td><td>Adobe Photoshop Color Control</td></tr>
</table>

Radial

A radial controller is more powerful in analog than digital. Not yet IOS or Android provides a radial controller. While users have already experienced with knob control through the home appliances, indeed, knobs and dials are intended to suit the needs, a digital user interface is potential to provide users simple and easy tasks for the control system. A few electronic devices introduced knobs and dials for the transitioned retro interface to control digital applications through the smartphones (Designmodo, 2013) ; adjusting volume control, radio channels, alarm set, timer control, and so forth. The advantage of the radial control is to control easily with the full set of parameters and data, but in digital frequency is still lacking other senses of human interaction such as haptic accuracy in infinite parameters. A physical structure of radial appears a control knob to be grasped by the fingertips. Fundamental functionality of a control knob typically increases and decreases input value by turning a rotary control (*Figure II-17*). A control knob is comprised of two different input systems; one is increasing/decreasing a value continuously, and the other has detents to produce a scale with a pointed setting (*Figure II-18*). According to Don Norman's the seven's stages of action (1998), the input control for a knob can be described as follows:

S.1) "Forming the goal" – Perceiving arrangement of functional values

S.2) "Forming the intention" – Understanding how to control and adjust values

S.3) "Specifying the action" – Presenting values and functions

S.4) "Executing the action" – Experiencing with using a knob control

S.5) "Perceiving the state of the world" – Turning a knob as perceived information

S.6) "Interpreting the state of the world" – Operating by input control action.

S.7) "Evaluating the outcome" – Functioning as the way it controls

Figure II-17. A control knob for continuing values control[40]

[40] Image retrieved from http://curtosappliances.com/wp-content/uploads/2011/01/wolf_knobs_df.jpg

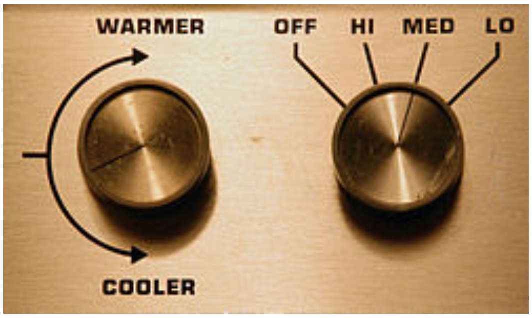


Figure II-18. A control knob for two different input system[41]

A radial control with a knob is also designed for selecting the desired setting instead of adjustment. This concept of interface design is useful in a controller providing multiple menus in a limited interface panel (*Figure II-19*).

FigureII-19. A control knob for menu selection[42]

The determination of the function of the device needs to be easy to know why the knobs are there. Moreover, Norman follows principles of visibility and proper mapping which are significant concerns when digital interfaces are presenting graphical information. *Figure II-20* introduces various UI designs with a knob controller. While the analog interface has limited interactive responses of interpretation of what input is doing, a graphic user interface (GUI) provides an enormous amount of visual perception for users and also interface presents various styles for affordable control information.

[41] Image retrieved from https://en.wikipedia.org/wiki/Control_knob#/media/File:Knobs-for-climate-control.jpg
[42] Image retrieved from http://www.raindialexchange.com/Irritrol-RD-Photo-History.html

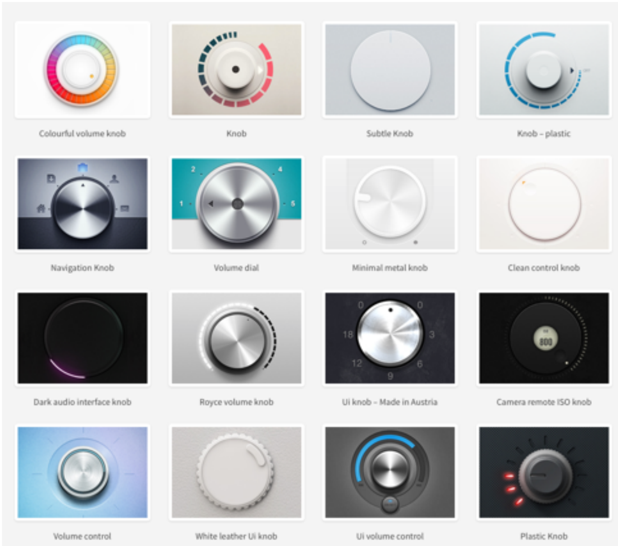


Figure II-20. Knobs and dials for digital interfaces[43]

2.4.4. Affordance Design

The word, "Affordance" was coined by Gibson, who was an American psychologist worked in the area of visual perception. Its theory refers to the actionable properties between the world and an actor (a person or animal) in nature (Greeno, and Kintsch, 1994). The theory of affordance began with explaining a relationship between objects and environment as how two different natures are existing and interacting for being easily discoverable. An object as an invariant to an observer always perceives an affordance. The affordance is not perceived by a need of an observer. Instead, it should be an object appearing an inerrant characteristic to perceive what it is in nature. The object offers the meaning of value throughout the environment such as being objective, real and physical within the perceived affordance elements; form, color and texture (Gibson 1979). These values specify the stimulus variables of visual sensation. The value of affordance needs to be perceived immediately and directly as a human being learned "how to use" or "what it is" naturally. It

[43] Image retrieved from http://www.uiparade.com/skill-type/knobs/

does not have to be visible, known, or desirable. The child plays a toy with a natural sensation of the animal in which observing and perceiving by optical responding enables a baby to use hands, body and mouth to approach interactive plays.

Norman addresses affordance as perceptual information (Norman and Pemberton, 1999). The device and products appear the critical clues of how to operate. Norman addressed three major dimensions to underline: conceptual models, constraints, and affordances while he believes that conceptual model is the most important part of a successful design. A physical product provides both “real” and “perceived” affordance but a screen-based interface is operated by only perceived affordances. Even though computer system is comprised of real affordance with physical accessibility such as keyboard, mouse, mouse pen, trackpad, etc., “affords clicking” of the graphic objects on the screen is only perceiving targets while users also may click anywhere on the screen. This phenomenon is related to an error of physical constraints. Except being taken action for the target, other actions should not be activated for the real affordance. This means, clicking on the screen for no responses is not necessary to be desired, but to be constrained. A convention is a constraint that makes some actions impossible, but it is not affordance. However, conventions can be created when users adopted affordances through daily experiences. It is important to designers to consider how the physical product needs to convey affordable information through the physical attributes, composition, and shape. Enhanced visibility and usability of a product were discussed with many design community (Norman 1988). Affordance is about the visual cues that indicate functional properties through the perceptive information. Norman (1998) provides a couple of examples for the concept of affordance through everyday objects:

- *"A chair affords ('is for') support and therefore, affords sitting. A chair can also be carried"*
- *"Glass is for seeing through, and for breaking"*
- *"Wood is normally used for solidity, opacity, support, or carving"*
- *"Flat, porous, smooth surfaces are for writing on"*
- *"Plates are for pushing"*
- *"Knobs are for turning"*
- *"Slots are for inserting things into"*
- *"Balls are for throwing or bouncing"*

Gibson (1979) argued, *"The object offers what it does because it is what it is"*; Moreover, this statement underpins that a product should provide users a clear understanding of visual perception based on "Form follows function." One of Gibson's affordance concept approaches to visual perception as a descriptive formulation; *"Water ... affords drinking. Being fluid, it affords pouring from a container. Being a solvent, it affords washing and bathing. Its surface does not afford support for large animals with dense tissues"* (Gibson 1979). This argument is in regards to the perception of affordances in the environment. It describes how visual perception can be picked up directly organism without mental control (Bruce, Green and Georgeson, 1996).

The notion of affordance is a very useful cognitive instrument involving perception with action (Albrechtsen, Andersen, Bodker, & Pejtersen, 2001; Norman, 1990). In a development of product functions, a relation between aesthetics and affordances is important to consider usability issues whether a product provides users perceptive information of the product functionality. Aesthetics has been considered in the interaction design community as how design interfaces for its aesthetics approach the abstract notion of beauty or its correlation to usability issues (Norman, 2004). Effective usability is a significant role in human-computer interaction (HCI) as how the interfaces integrate with aesthetics and affordance (Xenakis and Arnellos, 2013). When designers confront decisions to make successful design, aesthetics appear to be the most crucial in the design process. Both aesthetics and affordances need to be carefully measured for product success when designers consider the role of each one in the design process. Andersen and Pold introduce the role of artistic practices and aesthetic theory in interface culture; "*How interfaces are related to culture, and how art has developed around interfaces, often undermining common conception of the interface….. An aesthetic aspect of the interface is usually subordinated to a functionalistic or a stylistic dimension*" (Andersen and Pold, 2011). All interfaces are informative visualization that translates signs and signals within interface aesthetics linked to our perception of the technical infrastructures. An ideal of the affordable interface is 'user-friendly' visuals and metaphors between hardware and software. *"If success in communication was once the art of reaching across the intervening bodies to touch another's spirit, in the age of electronic media it has become the art of reaching across the intervening spirit to touch another's body. Not the ghost in the machine, but the body in the medium is the central dilemma of modern communication."*(Peters, 1999). Communication technologies working close to the skin can connect bodies – to transfer signals from one body to another body's skin, thus creating a sensation on another person. Allowing people to interpret the connections, their signals, and their signs, so that the interface does not try to penetrate the skin but instead aims to keep the interface at the skin, where the sign system will not be bypassed but will become embodied instead.

2.4.5. Human Factors and Ergonomics

According to the theoretical concept of human Factors, products as being "pretty" does not mean by being functional or easy to use. Functionality and ease of use of the product needs to appear the capabilities that provide users comfortable level (Maddox, 2008). Several scholars and researchers have contributed the finding of the relationship between product and the human body as how human factors and ergonomics should measure it. Henry Dreyfuss (2003), one of American industrial designer who contributed the new field of human factors, demonstrated how products should consider human body first when designers develop physical construction. He claimed human ergonomics-focused on the design of products for different sizes and shapes of people (Huston, 1994). *"A procedure for developing Intuitive and Ergonomic Gesture Interfaces for Man-Machine Interaction,"* written by Michael Nielsen, Moritz Storring, Thomas B. Moeslund, and Erik Granum (2003), addresses important considerations of awareness with motions and ergonomic principles. The approaches to address important issues in gesture communication was from a technological viewpoint as well as a user viewpoint use as the technological complexity, learning rate, ergonomics, and intuition.

All computer devices we use every day are getting more intelligent as much as it provides less memory task required to interact with the information processing sequences. The consideration of the ergonomics in product design determines the best ways to perform any designated tasks by users' productivity and safety (Stanton, 2005). Cognitive psychology and human behavior became much more important to examine informative process (Reigberg, 2006). In addition to communication and interaction with a product in human beings, users' command to interact with computer system creates a type of communication methods.

Computer users respond to visual information such as text, image, color, texture and sound that are appearing on the devices as perceptive behaviors from human senses. In approaching visual communication within UX and UI design, designers consider how users perceive visual information as more common sense, knowledge, and experiences rather than logical and scientific attitudes (Dix, 2004). However, it seems like the modern technology study is more complicated to figure out what it could be simply understandable and easier to interact with users. Reigberg (2006) believed that the consequences should be satisfying for "everyone", but research processing should be considered for the "individual." This refers to finding problems through individual users direct to the common knowledge for everyone.

Since smartphone touchscreen is a most frequency of primary interaction from the users' everyday usages in ergonomics studies, Xiong and Muraki (2014) claimed the figure gesture and thumb movement. The research investigated the relationship between thumb muscle activity and operating tasks on a smartphone touchscreen with one hand posture. Adult fingers typically have a diameter of 16mm to 20mm (Danderkar, Raju and Srinivasan, 2003). For pushing a physical button or a virtual icon on touching screens, it is common that the pad of the finger is used for touch-based action rather than the tip. Fingertips are narrow, only 8-10mm wide and finger pads are wider than fingertips, but narrower than the full finger, typically 10-14mm. *Figure II-21* is an analysis of the ergonomics for hand data from Henrry Dreyfuss's book, "Designing for people." Dreyfuss created these composite figures from his research and experience in human physiology that knowing such information helped designing everything from tanks to telephones. The analyzed hand data shows significant ergonomic concerns for the interface design on a smartphone as how users interact with virtual buttons and interface layout.

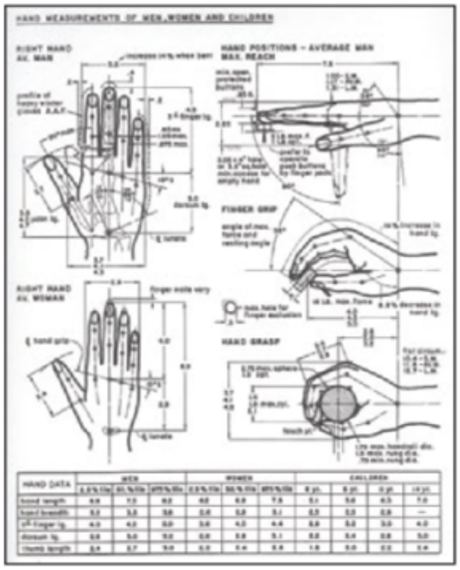


Figure II-21. Ergonomic figure of hand data[44]

Another ergonomic problem arises with a gestural interface in that, because there is typically no wrist support, using one for a long period can be tiring on the hand and fingers. This especially true with touchscreens, because often, significant pressure is required to engage them, and the screens, being made of glass, don't bend or give. Because of the inaccuracy of our fingers and hands, it is best not to make similar gestures for different actions in the same system for fear of users accidently triggering one instead of the other.

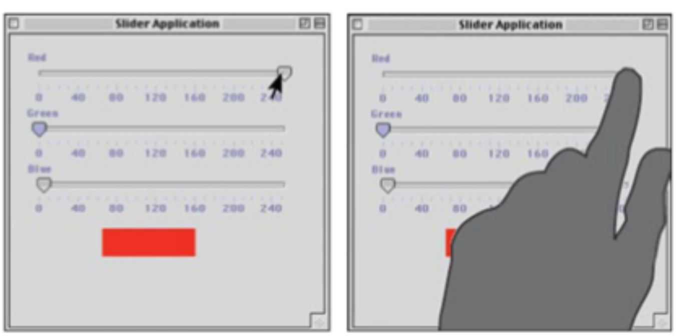


Figure II-22. Ergonomic figure of hand data: Saffer, Dan (2008, p40)

[44] Image retrieved from http://www.learneasy.info/MDME/MEMmods/MEM30008A-EcoErgo/Ergonomics/images/hand-dimensions.png

Unlike a mouse cursor, our finger pads do not float transparently in space, the rest of the finger, the hand, and the arm will likely cover up some part of the interface while the user is touching it, especially the part of the screen immediately below what the user is interacting with. Thus, it is good practice to keep the following warning in mind. *Figure II-22* illustrates the difference between designing for a cursor and designing for a hand. The hand covers up not only the labels on the slider but also the display showing the color that is being created. Fitts Law (1992) has affected many different fields, especially creating products related to software such as computer science, engineering, industrial design, etc. Fitts' Law simply states that *"…the time it takes for a user to reach a target by pointing with a finger or with a device such as a mouse is proportional to the distance to the object divided by the size of the object. Thus, a large target that is close to the user is easier to point to than a smaller one farther way."*

2.5. Related Works

As this study addressed the development of mobile game applications for touchscreen basis input control, the mobile game industry has introduced a variety of contents and game methods. In 2009, there were 21, 178 games and entertainment apps available in the Appstore (Topols**k**y, 2009). According to the resource of the current application category distribution in Appstore, there are 540, 540 games and 146, 304 entertainment apps available which are ranked as the top level of the entire category *(Figure II-23).* This result addresses that the game industry through the mobile network and touch-based smartphone game has increased over more 32 times bigger in last seven years. However, there are a few empirical studies related to a comparison of the effectiveness of touchscreen-based and physical input controls. This study demonstrated related studies to approach research methods for the usability test as compared to two platforms in human subjects.

Current Active Application Count By Category		
Category	Total	% of Total
Games	540,540	23.32%
Business	236,734	10.21%
Education	213,780	9.22%
Lifestyle	200,683	8.66%
Entertainment	146,304	6.31%
Utilities	115,778	5.00%
Travel	96,131	4.15%
Book	73,046	3.15%
Health & Fitness	68,438	2.95%

Figure II-23. Current active application count by category (App Store Metrics, n.d.)

2.5.1. Touchscreens and Hand Gesture Interaction

Discovering user-friendly basis on touchscreen input control has been significantly important to many researchers. The touchscreen in user interaction has been ambiguous due to a difficulty of control by finger touch- a selection of a point in terms of small size on the screen. Dan Saffer demonstrated finding the patterns for touchscreen and an interactive surface on the touchscreen such as tapping, dragging, sliding, spinning, holding, flicking, flinging between one and two finger controls (Saffer, 2008). Touch-based interaction is also considered to be respond to touch, either by finger or by the use of a stylus on the touch-sensitive display. *Figure II-24* shows touch gesture reference guides with one and two hands gestures that describe interactive input tasks on touch-based screen. However, many users are not familiar with all gestures in terms of a lack of experiences and sustainability in a frequency of use. In fact, users, especially in experience with the touchscreen-based mobile device, execute mostly tapping and dragging by given input control tasks. However, there are not enough empirical researches available yet to claim the effectiveness of input control with hand gesture-driven gameplay on a touchscreen. With over 500,000 games in Appstore, game genres can be categorized by one or two hands control. One hand control-based game came out was introduced when the smartphone came out. One hand input task was controlled by not just only tapping, but also dragging and press-holding. Moreover, this finger gesture typically provides users a simple control in a configuration of movement or shooting. Some games are designed for two hands input control when both input tasks are required to play. A few studies have introduced "Direct Manipulation" interface to address the effectiveness of hand gesture control guides.

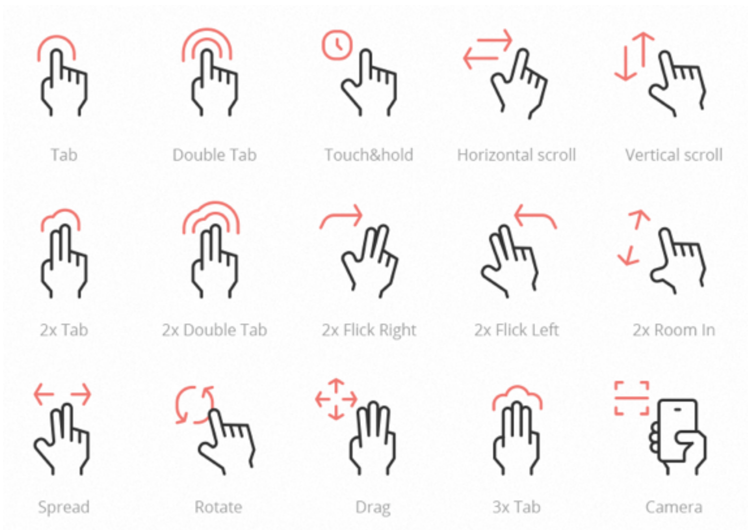


Figure II-24. Touch gesture reference (Luke W, n.d.)

Direct manipulation interfaces are defined as *1) "continuous representation of the object of interest"* (Hutchins, Hollan, & Norman, 1985), *2) "physical actions or labelled button presses instead of complex syntax"* (Hutchins, Hollan, & Norman, 1985), and *3) "rapid incremental reversible operations whose impact on the object of interest is immediately visible"* (Shneiderman, 1984). Shneiderman created these principles to follow user-friendly novel that addresses positive feelings of Human-Computer Interaction;

- *"Mastery of the interface"*
- *"Competence in performing tasks"*

- *"Ease in learning the system originally and in assimilating advanced features"*
- *"Confidence in the capacity to retain mastery over time"*
- *"Enjoyment in using the system"*
- *"Eagerness to show the system off to novices"*
- *"Desire to explore more powerful aspects of the system"*

Kown, et al. (2011) also underlined three considerations with conventional direct manipulation. Manipulating objects are not effective in conditions when objects on the touchscreen are small or distant. It is not effective either when objects that have many attributes and are densely packed or in a limited space. Direct manipulation does not provide effectiveness to interact intangible object properties. Hartman, Klemmer and Takayama (2006) emphasized consideration of the significant interaction on human embody engagement; 1) Thinking by doing between both physical and mental activity, 2) Performance with advantage of kinesthetic memory by consistently dedicating physical movement to interface functions, 3) Visibility in the workplace for perceptive satisfaction, 4) Risk to decision-making process, and 5) Thickness of practice in correspondence between the technology and the real world.

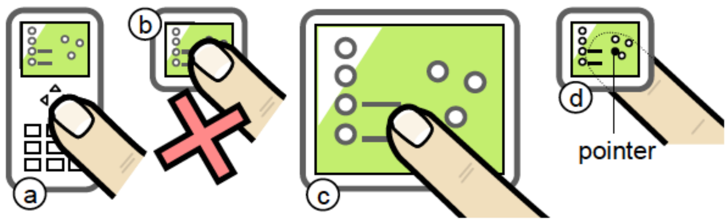
Gesture Based Interaction (GBI) on a touchscreen device is comprised of two different interactions; 1) Surface and 2) Motion gestures. Wobbrock, Morris and Wilson (2009) claimed users would choose a distinct lack of the understanding of the reliable perception rather than what gestures. This means that user-centered design is the foundation of HCI that is developed gestural interaction naturally by users. According to the study by Mauney, et al. (2010), users who had prior experience with gesture-based devices showed better performance than users in less experience with non-technical gestures. Furthermore, in finding of the study, one hand gestural interfaces are more effective and satisfied with touchscreen devices. Motion gesture is another input modality on touchscreen devices that provide motion sensors for a change of the orientation. Motion gestures require human behavior implemented by a new dimension. Rico, Crossnan and Brewster (2011) conducted a study to address a lack of formality about gesture design through 20 users, and they found that users perceived that an interface would be unable to recognize input control successfully, but they accepted errors and failure of gestural interaction positively.

The tactile input control for touchscreen is another importance for investigating the effectiveness of the touchscreen-based game design. Tactile interaction with touchscreen mobile device can be a potential solution to gaming issues with a lack of tangible sensibility for accuracy and effectiveness of the input control performance. According to Hoggan, Brewster and Johnston (2008), a lack of tactile feedback may cause problems for making mistakes and errors on touchscreen-based input control. They conducted an experiment to compare devices with a physical keyboard, a standard touchscreen and a touchscreen with tactile feedback added. As a result of this study, adding a tactile on touchscreen improved the users' performance close to the effectiveness of physical keyboard. Participants were able to enter text accurately with a tactile keyboard on a touchscreen when they move on or even with the disturbance caused by the train. Moreover, recent research introduced the improvement of usability for a mobile game with vibrations on technical acceptance (Choe and Schumacher, 2015). The study focused on vibrations as a haptic feedback and analyzed the influence of intensity and length of vibrations on user perceptions. Through the implementation of the experiment with 70 participants, the result showed that accepted vibrations significantly increased the effectiveness values such as perceiving ease of use, usefulness and cognitive concentration in the game regardless the length of vibration to be a critical factor.

2.5.2. Touchscreens vs. Analog Input Control

Smartphone game users expect that playing a touchscreen-based game is easy and intuitive on input control interaction. All manufactured analog input control is set with fixed input control interface with size, some buttons, and position. Graphic user interface (GUI) on touchscreen appears itself visible and invisible that touchscreen-based input control is flexible to be user-friendly. Mobile game developers may create the input control with this advantage such as modifying the layout according to the game context and moreover, this investigation can improve the accessibility of the game interaction for diverse age, gender and disability group (Pelegrino et al., 2014).

Analog (Physical) input controls such as a button, joystick and knob have introduced to game users to interact with the game performance. This study also reviewed the history of gaming consoles in the literature of gaming environment to understand the development of both touchscreen-based input control and physical input controller. A small and limited space of the touchscreen demands the need for other physical input mechanisms. Patrick Baudisch and Gerry Chu (2009) explored pointing input capability to very small devices. 'Back-of-device' interaction method is to avoid interference between fingers and screen in which this interaction provides a) separated pad, b) touchscreen of the corresponding size of a finger, c) larger touchscreen of usable size and d) back-of-device touch input control *(Figure II-25).* This study claimed that any pointing technique on the touchscreen devices could be problematic once the screen gets smaller to interact with contents. This finding arises a question as how mobile game on touchscreen-based input control can be more effective once the screen size is limited when smartphone games show heavy traffic with graphic information.



Note: The figure-2 (Baudishch & Chu, 2009)

Figure II-25. Pointing input on mobile device

Another consideration of touchscreen-based game is better performance with input control system. Zaman, Natapov and Teather (2010) presented a study which compares with touchscreen-based “virtual” controls and physical controls to measure the effectiveness of input control on the same game between iPhone and the Nintendo DS Lite in which level completion time and some player deaths were evaluated. The result appeared that physical buttons on Nintendo DS allowed participants significantly better performance than a virtual button on iPhone touchscreen despite all participants performed the game achievement better after they adopted the familiarity of a game input control interface on the touchscreen.

In a similar finding with this study, Oshita and Ishikawa (2012) demonstrated a comparison of action selection user interfaces in computer games to provide a guideline for choosing and designing interfaces for computer games. In this study, gamepad (game console) and touchscreen interface were compared to accuracy and responsive level since handheld game consoles such as Nintendo DS and Will U are intractable action input control with both a gamepad and a touchscreen. This study experimented with an action displayed on the screen and selecting the subject on screen was measured by the number of errors and selection time. The research found that touchscreen interface achieved better or similar result to the gamepad interface in which findings are different from the result of a study by Zaman et al. (2010). Other related studies discovered similar result on the target selection tasks such as using the touchscreen to shift (Vogel and Baudisch, 2007), rubbing and tapping (Olwal et al., 2008), and finger orientation (Wang et al., 2009). All these research focused on the evaluation of touchscreen interfaces and devices. Therefore, this study needs to seek empirical research analysis with a human subject to provide guidelines for input control interface design on touchscreen devices.

Touchscreen game design also introduced untouchable input control method. Teather and Mackenzie (2014) recently conducted a study comparing touch and tilted-based game control methods to find an order of control: Position-control and velocity control. The research was evaluated for game-level reached and how frequently the ball was missed. The study also focused on consideration in game control such as direct vs. indirect touch input control and tilt input control in gaming performance. The result was that order of control is more important than input control method regardless implementation with touch or tilt input. With findings, this study recommended game developers to consider tilt and touch control input options as 1) offering both touch and tilt input, 2) considering position-control mappings, 3) providing flexibility of changing size of input control, and 4) allowing changing control positions.

The control mechanisms in mobile games may be discussed with immersive experiences such as tilting and mixed input control actions between touch and tilt. Since mobile device fits into the held screen orientation input control by itself, game developers may need to consider immersive input control in different perspectives. Recent research introduced experiments of two tasks to measure the influence of immersive control in mobile games (Cairns et al., 2014). The study found that using a tilting input control resulted in a higher level of immersion and substantial effect. Motion interface by using a device moving orientation is efficient due to no required GUI considering size, location frequent actions on touch. Another finding in the study was related to a comparison of control mappings. Unlikely effective tilt on the racing game, the tilt was not significantly more immersive than touch on the game when it requires the orientation change as a movement instead of direction.

2.5.3. Analysis Methods for Measurement and Evaluation of Usability Test

The purpose of usability typically to measure the quality-in-use of interactive computer usages (Bevan, 1995). The quality of use can be measured by usability task achieved with effectiveness, efficiency and satisfaction by users;

- *"Effectiveness: The accuracy and completeness with which users achieve specified goal in particular environments."*
- *"Efficiency: The accuracy and completeness of goals achieved about recourses expended."*
- *"Satisfaction: The comfort and acceptability of using a system."*

The measurement and evaluation of usability test in user experience (UX) and user interface (UI) varies with subjects and variables from such as "*task completion time, error rates, subjective satisfaction, perceived workload, assessments of a work product's quality, feelings of enjoyment, questionnaires on ease-of-use, and so forth*" (Hornbaek and Law, 2007). In measuring effectiveness and ease of use by gameplay, usability test with human subjects are essential to approach both qualitative and quantitative values. Common measurement in qualitative method was applied to the statics analysis in which two-way analysis of variance result is compared. In a particular measurement of game achievement, several studies were collected the game score, a time length of the gameplay (MacKenzie, 2010; Pereira & Roque, 2013; Ruy,2010). Hornbaek and Law (2007) investigated 73 studies to provide information about how to select measures of usability to look at correlations between usability measures but show a mixed result. They found that task completion times and errors were often measured by comparison of the relative merits between two interfaces. Choe and Schumacher (2015) arranged the questionnaires of finding the effectiveness of usability; "*1) perceived usefulness, 2) perceived ease of use, 3) perceived enjoyment and 4) cognitive concentration.*" They adopted the Cronbach's Alpha Test for this questionnaire instrument in an investigation of the internal consistency in which all four determinants were calculated as being larger than 0.7 (Cronbach, 1951).

In regards to consideration of the usability quality, Dzida (1995) demonstrated that "*standard user-interfaces and standards for user interfaces*" should be distinguished. In his article, a standard user interface is related to presentation information such as style guides and toolboxes help design user-interface. The interface appears as being looked and felt by users to measure a quality of usability. However, standards for user-interface interprets establishing a minimum level of user-oriented quality. In software-ergonomic standards address that freedom of design, no required specific implementation, task or organizational setting. According to principles of usability on the user's task at hand, the information in the usability test should be presented one of more of following principles; legibility, comprehensibility, consistency, discriminability, detectability, conciseness, and conformity with user's expectations. In contrast with this, Shackel (1991) claimed that "the usability of a system is the capability in functional human terms to be used easily and efficiently by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of scenarios. However, Nielsen (1993) as another pioneer in the field of usability influences acceptability which is related to five attributes; learnability, efficiency, memorability, errors, and satisfaction.

In this review of the related studies, it is important to understand how to measure usability and how to analyze data values for user interface evaluation. According to to180 studies reviewed by Hornbaek (2005), a comparison between subjective and objective measures of usability may develop the methodology of the assessment for the achievement level of usability in gameplay. His study also suggested that consideration of challenge includes the need to extend satisfaction measures; to study correlations between measures, and to impulse the limitations of what we conceive as usability measures. All these reviews will refer to develop the methodology for the usability measurement and evaluation in this study.

CHAPTER III. METHODOLOGICAL FRAMEWORK FOR PILOT STUDY

According to the literature review, there have introduced many smartphone touchscreen gaming transformed from video and PC platform without consideration of the smartphone's user interface and interaction. All game consoles are limited to play games in terms of emulating issues by the touchscreen gaming providers. This restricted functionality allows smartphone users to play only limited games. In addition, some smartphone games are limited to enjoy with playing the game on the input control action on the directed touchscreen. Especially games required to interact with multi-input controls were already reviewed as several major discomforts by users. Therefore, third party manufactures have introduced a game controller for smartphone game users to improve touchscreen gaming. There are no empirical researches yet related to findings of different values between touchscreen provided in-house and a game controller provided by the 3rd party manufacture, so this study intended to find a comparison of user's comfortable level between touchscreen gaming and game controller gaming through the pilot study.

The purpose of this usability test was to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital (touchscreen) and analog controller in smartphone games. This research was also to discover effectiveness, efficiency and accuracy level of the digital interface on a smartphone while all smartphone games intended to control an input interface with finger(s) touches and hands gestures only. Finding positive usability with analog input controllers in this research may reflect developing a future smartphone with interface design as being affordable with an input control system.

3.1. Method of Usability Test in Pilot Study

The primary objective of this pilot study was fundamentally to discover an efficient level for input usability on smartphone gaming environment between analog and touchscreen. In addition, this study was to examine satisfactory levels from different types of game. The usability test was conducted as a pilot study comprised of two different groups as a small-scale experiment. Each group conducted tasks playing three different mobile games (Action, Arcade, and Casual) with and without an external game controller in a smartphone game. Group A conducted a test of playing games with a direct control interface on the smartphone touchscreen first, and then participants had another task for playing games with a game controller. Group B conducted a reverse way from the Group A. Participants conducted a test with a game controller first and touchscreen later. With the result in findings of the set of observations and exit interviews, this research will develop a full-scale experiment.

Participants' behaviors were observed as how they control input system with a finger(s) touch and a game controller. Control performance by users was also observed during a task to see how users make errors or mistakes in terms of interface design in both digital and analog controls. Video/audio (non-identifying) was captured, field notes may be taken, and computer activity data may be collected (i.e., a game control activity).

3.1.1. Description of Procedure

Participation spent approximately 60 minutes for conducting a usability test.

1) The PI contacted prospective participants to schedule a usability study and sent informed consent document.

2) On the selected date of the usability study, each participant was given a copy of the Informed Consent Document for review and to sign prior to the start of the session. If a participant agreed and signed the Informed Consent Document, the session began.
3) Information regarding the project was read before the session.
4) Each participant completed the pre-survey questionnaire regarding demographic information and their familiarity with the technologies.
5) The usability testing took place at GRA 241 at University of Nevada Las Vegas. All test activity from each participant was recorded as voice and/or video during the test. Participants' hand(s) and finger(s) movement was also recorded during playing a game. Participants will not be identified in any future video use (i.e. video will not include face).
6) The participants performed a series of tasks on the interface design of playing a smartphone game. They may skip any tasks if they do not wish to perform or that makes you feel uncomfortable.
7) All participants completed a brief exit survey and interview after the usability testing.

3.1.2. Game Information

For evaluating input usability (actions and control movement) compared with touchscreen and game controller, this test was comprised of playing three different types of games (Action, Arcade, and Casual). These selected games are reviewed as smartphone game-environment-friendly in terms of touchscreen based driven. Each game was chosen by consideration for users who may be familiar with common game rules from their experiences. Games are comprised of different input tasks; movement only, movement & jumping, and movement & occasional bombing).

Testing Games

Participants will conduct three different genres of smartphone games.

A. Causal game: PacMan (Movement only)

PacMan is a traditional video game which allows players to gain points as PacMan eats a dot. Each character tries to catch PacMan that a player is moving around a map on each level. Each level is designated by the number of dots, and the character accelerates on a speed of character movement when a certain number of dots remained.

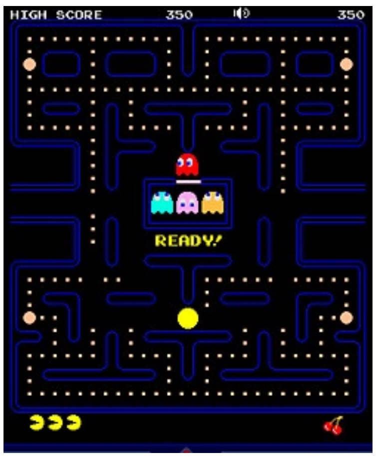


Figure III-1. PacMan game screen snapshot

B. Arcade Game: Meganoid (Movement & Jumping)

Meganoid is a similar arcade game with Mario video game which allows players to explore the map on each level. The character can move forward/backward/jump to complete the task with obtaining a game coin during a game. As the game level moves up, the map is more complicated, especially difficulties with jumping.

Figure III-2. Meganoid game screen snapshot

C. <u>Action game: AirAttack (Movement & Occasional bombing)</u>

AirAttack is a simulation of the air battle which allows players to attack enemies. Players need to move the airplane in order to avoid enemies' attacks while they are moving towards the strongest enemy's aircraft ship on each level.

Figure III-3. AirAttack game screen snapshot

Game Controller

MOGA Mobile Gaming System for Android 2.3+: This product is ranked the top selling record in the amazon.com. Over 1000 consumers reviewed pros/cons.

MOGA is a portable game controller with dual analog sticks, shoulder triggers, and four action buttons. It is simply synced with a smartphone through Bluetooth between smartphone and controller. This type of mobile controller allows game users to play plenty of hardcore games which are still very difficult to control on touchscreens. <*http://www.ign.com/articles/2012/10/18/moga-mobile-gaming-controller-review*>

Even there is various type of mobile game controller introduced in the game market; there are still limited to a number of games to access in terms of OS' support. The controller is designed to clip various type of smartphones and easy to carry on.

Figure III-4. MOGA Mobile Game Controller

Smartphone

- Screen size: 5.7" (~74.8% screen-to-body ratio)
- Resolution: 1080 x 1920 pixels (~386 ppi pixel density)
- Dimensions: 151.2 x 79.2 x 8.3 mm (5.95 x 3.12 x 0.33 in)
- Weight: 168g (5.93 oz)

Figure III-5. Samsung Galaxy Note 3

3.1.3. Implementation of Usability Test

In order to implement the usability test, the principal investigator (PI) applied the IRB on October 5, 2015 and the final approval was confirmed on December 4, 2015. In terms of the PI's circumstance, the pilot study was designated on the University of Nevada, Las Vegas campus. A usability test was conducted with total six participants who agreed to be part of the human subjects for the pilot study. Each participant was contacted by the PI's instruction and accommodation for the usability test. In the beginning of the usability test, each participant obtained a brief instruction of the study including the purpose of the study and each game's instruction. After that, participants signed the agreement with the Informed Consent Document.

Tasks and Guidelines for playing a game

- The order to play game is A) PacMan, B) Meganoid and C) AirAttack. According to the frequency of similar input actions between PacMan and AirAttack, Meganoid was listed as the second game to avoid an indirect effect on gaming satisfactions.
- Group A conducted it with a touchscreen mode, and Group B began it with a game controller.
- Participants were allowed to play each game up to five (5) minutes. If anyone plays over the maximum time, PI asked them to stop playing a game.
- After completion of all tasks for the usability test, participants were asked to fill out the open-ended survey and discussion of additional comments with the PI.
- Evaluating for the achievement of each game was based on the time-length since the usability test focused on the user interface design between touchscreen and a game controller. However, each game was limited by playing the game maximum 5 minutes and achieving game level was not considered for the evaluation due to delaying the game length of obtaining items and points.

3.2. Result and Findings of Pilot Study

3.2.1. Analysis of Demographic

Participants were comprised of current undergraduate students at UNLV. According to the frequency of using a computer daily, there was no consideration of a lack of prior experience or knowledge of using computer devices from participants. Even though P2 and P3 have never played a video/PC game, they felt comfortable to play a smartphone game. However, a test needed attentions to compare the result between P4 and P6 since two participants showed most and least experience with playing digital games.

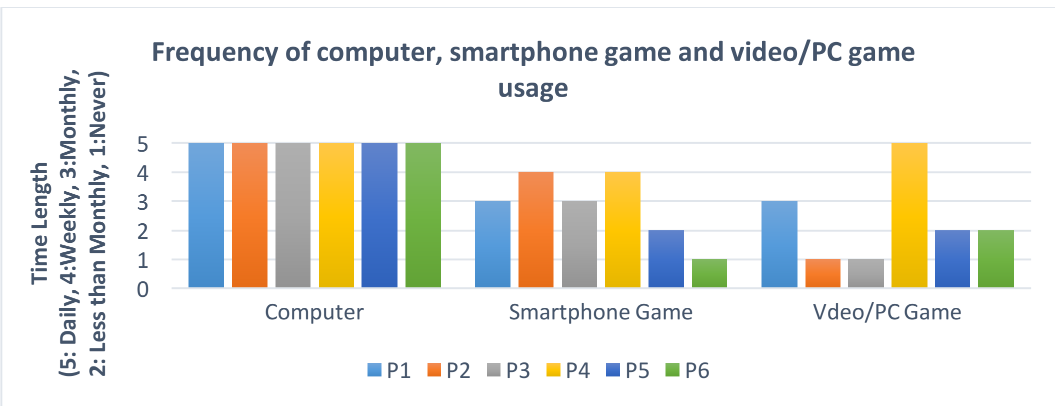


Figure III-6. Analysis of computer, smartphone game and video/PC game usage

- Male: 2, Female:4
- Age: 18-23: 2, 24-29: 3, 30-35: 1
- Smartphone use: IOS(Apple): 4, Android:2
- All participants are comfortable with using computers and tablets.
- 5 participants are comfortable with using a smartphone, and 1 participant is slightly comfortable.
- 3 participants use Mac, 2 participants use both Mac & PC, 1 participant uses PC.

- All participants use a computer daily.
- 1 participant never play a smartphone game, 2 participants play weekly, 1 participant plays monthly, and 1 participant plays less than monthly.
- 2 participants never play a video/PC game, 1 participant plays daily, 2 participants play less than monthly, and 1 participant plays monthly.

3.2.2. Result of Usability Test in Pilot Study

Table III-1. Group A: playing a game on the touchscreen first

P1. (Female)

Game	Touchscreen		Game Controller	
	Time (min.)	Level	Time (min.)	Level
A	5:00	4	1:32	1
B	1:34	3	2:27	8
C	5:00	N/A	5:00	N/A

P2. (Male)

Game	Touchscreen		Game Controller	
	Time (min.)	Level	Time (min.)	Level
A	4:35	3	1:45	2
B	1:51	6	3:13	9
C	5:00	N/A	5:00	N/A

P3. (Female)

Game	Touchscreen		Game Controller	
	Time (min.)	Level	Time (min.)	Level
A	4:27	3	3:35	3
B	1:33	3	2:48	8
C	3:40	N/A	2:54	N/A

Table III-2. Group B: playing a game on the game controller first

P4. (Female)

Game	Game Controller		Touchscreen	
	Time (min.)	Level	Time (min.)	Level
A	4:32	3	5:00	4
B	3:19	9	2:36	9
C	5:00	N/A	5:00	N/A

P5. (Female)

Game	Game Controller		Touchscreen	
	Time (min.)	Level	Time (min.)	Level
A	2:43	1	5:00	2
B	2:53	6	2:02	4
C	5:00	N/A	5:00	N/A

P6. (Male)

Game	Game Controller		Touchscreen	
	Time (min.)	Level	Time (min.)	Level
A	2:18	2	4:19	3
B	2:26	8	2:48	4
C	5:00	N/A	5:00	N/A

Figure III-7. Analysis of time length for user achievement on each participant

- Playing a game in a different order with touchscreen and a game controller did not appear any significant differences between two groups.
- There was no different result between male and female demographic. Both genders played all games as similar results.
- The result of evaluation for the time length of playing games appeared similar among the participants.
- All participants played the Game B (Meganoid) shorter than other games with both touchscreen and a game controller. However, P1, P2, P3, P4 and P5 played the game

with a game controller longer than a touchscreen, especially, P2 and P3 played longer than one minute when they use a game controller. This result shows evidently that playing the game for two control actions (movement and jump) is more effective when a player uses a game controller.

- A significant result from the Game A (PacMan) was that all participants played it with a game controller much shorter than paying on the touchscreen. Among the participant P1, P2 and P5, the difference of time length for playing this game was over 3 minutes. However, 3 participants responded this game on a touchscreen as the most frustrating game.
- Playing Game C (AirAttack) appeared that all participants played almost 5 minutes through both touchscreen and a game controller. In addition, 4 participants responded that this game was the most comfortable to play on a touchscreen.

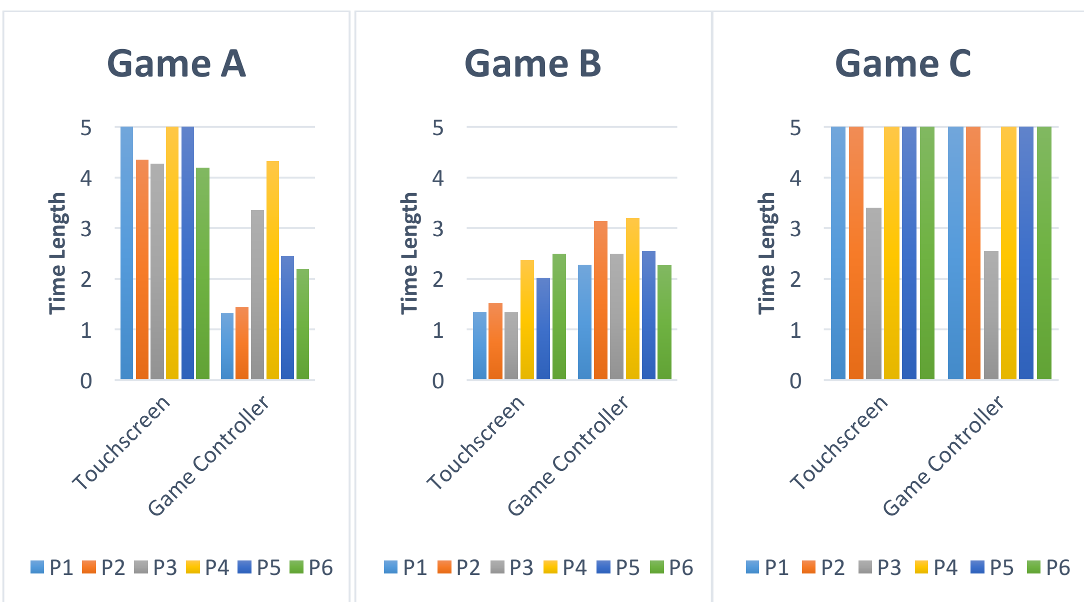


Figure III-8. Analysis of time length for user achievement on each game

- Game A appeared that participants played the game much longer with a touchscreen.
- Game A appeared much more different numerical value of playing the game between touchscreen and a game controller: The different result of P4 from others may cause the fact that P4 is only one who plays a video/PC game everyday. Excluded P4, the result is obvious to see each participant had a difficult time to play the game longer with a game controller.
- Even though Game B appeared that participants played the game a little longer with a game controller, Game B was the most difficult to play the game last longer compared to other games.
- Game C appeared that participants played the game 5 minutes with both touchscreen and a game controller. In terms of this result only, there were not many comparisons between two conditions.
- Achievement of Game B based on the game level. According to the type of Game B as less time consuming for playing a game, this game was evaluated the comparison of achievement based on achievement of the game level.

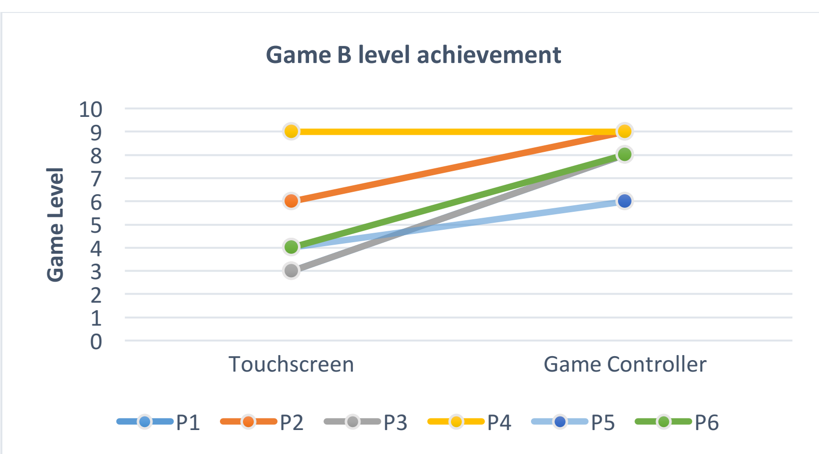


Figure III-9. Analysis of game B level achievement

The Game B is arranged in levels from 1 to 10. All participants achieved the level better with a game controller. P3 reached 5 levels more with a game controller. P4 does not show any difference between two conditions, but P4 responded that Game B was the most comfortable to play with the game controller. Thus, this result reflects that more than one input control action is easier when a player uses a game controller.

Summary of Findings

- Game A appeared that touchscreen is more effective to play the game longer.
- Game B appeared the most difficult game to control. All participants played Game B for the shortest among other games.
- Game C appeared the easiest game to control. Participants played the game up to 5 minutes in both touchscreen and game controller. P3 played less than 5 min, but the result shows a similar length of playing time in both touchscreen and game controller.
- The effectiveness of touch screen control: Directed movement > Directed movement & occasional shooting > Frequent movement and jumping. This result reflects a lack of clarification and effectiveness of user interface development guidelines for the game design industry.

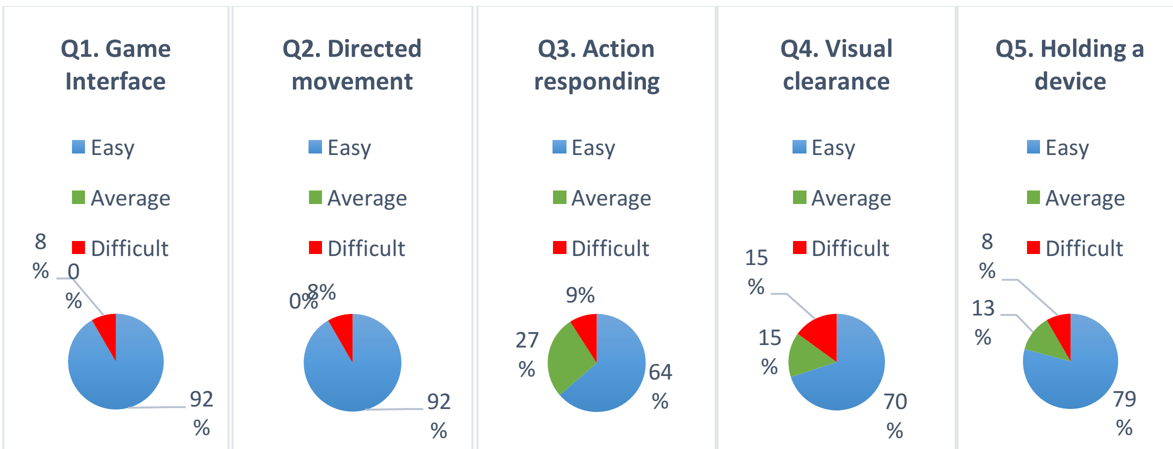
3.2.3. Analysis of Exit Surveys

Table III-3. Responding comfortable level on touchscreen

	Questions		**5**	**4**	**3**	**2**	**1**	
Q1	Overall, how easy was it to control the game interface by the touchscreen?	Easy	2P	3P		1P		Difficult
Q2	Overall, how easy was it to control the directed movement by the touchscreen?	Easy	2P	3P		1P		Difficult
Q3	Overall, how easy was it to control actions such as jump and shooting by the touchscreen?	Easy	2P	1P	2P	1P		Difficult

Table III-3. continued

Q4	Overall, how easy was it to look at the screen during playing a game?	Easy	2P	1P	1P	1P	1P	Difficult
Q5	Overall, how comfortable was it to hold the smartphone during playing a game?	Comfort	3P	1P	1P	1P		Discomfort



Comfortable level: *v=easiest 5*, easy 4*, average 3*, difficult 2*, and most difficult 1**

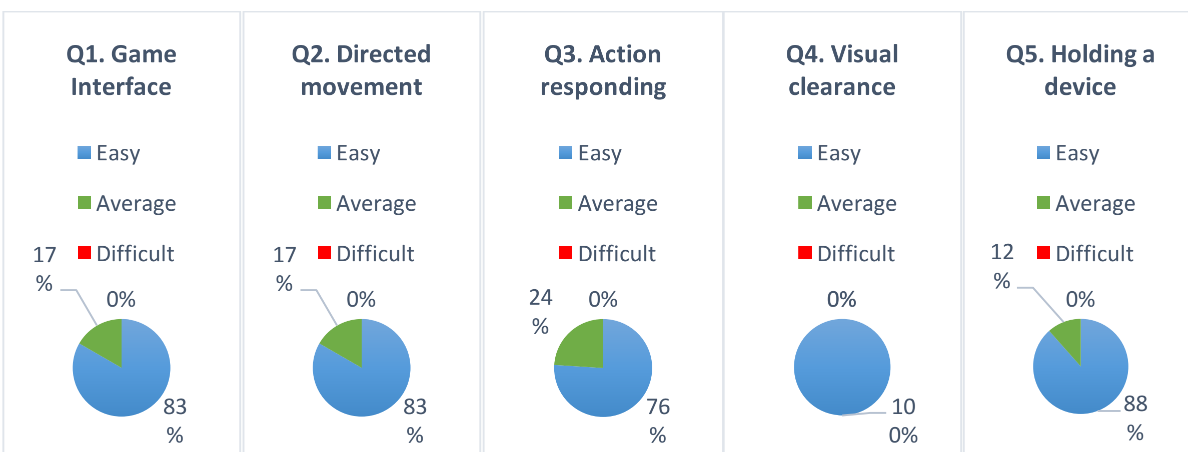
Figure III-10. Responding comfortable level on touchscreen

- Overall, all participants are comfortable to play a game on a touchscreen.
- Comfortable level for game interface to control input action was ranked as 92% easy to play a game among the participants.
- Comfortable level for the directed movement of the object by finger touch was ranked as 92% easy to play a game among the participants.
- Comfortable level for the control action (jumping and shooting) on the touchscreen was ranked as 64% easy to play a game among the participants. However, participants who responded to it as positive mentioned that control for the length of jumping on Game B was difficult.

- Comfortable level for visual clearance on the screen while participants are blocking a part of the screen with a finger was ranked as 70% easy to see the screen during playing a game.
- Comfortable level for holding a smartphone was ranked as 79% easy to play a game.

Table III-4. Responding comfortable level on game controller

			5	**4**	**3**	**2**	**1**	
Q1	Overall, how easy was it to control the game interface by the game controller?	Easy	2P	3P	1P			Difficult
Q2	Overall, how easy was it to control the directed movement by the game controller?	Easy	4P		2P			Difficult
Q3	Overall, how easy was it to control actions such as jump and shooting by the game controller?	Easy	3P	1P	2P			Difficult
Q4	Overall, how easy was it to look at the screen during playing a game?	Easy	6P					Difficult
Q5	Overall, how comfortable was it to hold the game controller during playing a game?	Comfort	3P	2P	1P			Discomfort



Comfortable level: *v=easiest 5*, easy 4*, average 3*, difficult 2*, and most difficult 1**

Figure III-11. Responding comfortable level on game controller

- Overall, all participants are comfortable with playing a game with a game controller and there were no negative responses.
- Comfortable level for game interface to control input action was ranked as 88% easy to play a game among the participants.
- Comfortable level for the directed movement of the object by a game controller was ranked as 83% easy to play a game among the participants.
- Comfortable level for the control action (jumping and shooting) with using a button on the game controller was ranked as 76% easy to play a game among the participants.
- Comfortable level for visual clearance on the screen was ranked as 100% easy to see the screen during playing a game.
- Comfortable level for holding a game controller was ranked over 88% easy to play a game.

Table III-5. Comparisons for comfortable level between touchscreen and game controller

		Touchscreen	Game controller	Both	None
Q1	Which performance was easier to control the game interface?	3P	1P	2P	
Q2	Which performance was easier to control the directed movement?	3P	3P		
Q3	Which performance was easier to control actions such as jump and weapon?	1P	4P	1P	
Q4	Which performance was easier to look at the screen during playing a game?		5P	1P	
Q5	Which device was more comfortable to hold during playing a game?	2P	3P	1P	

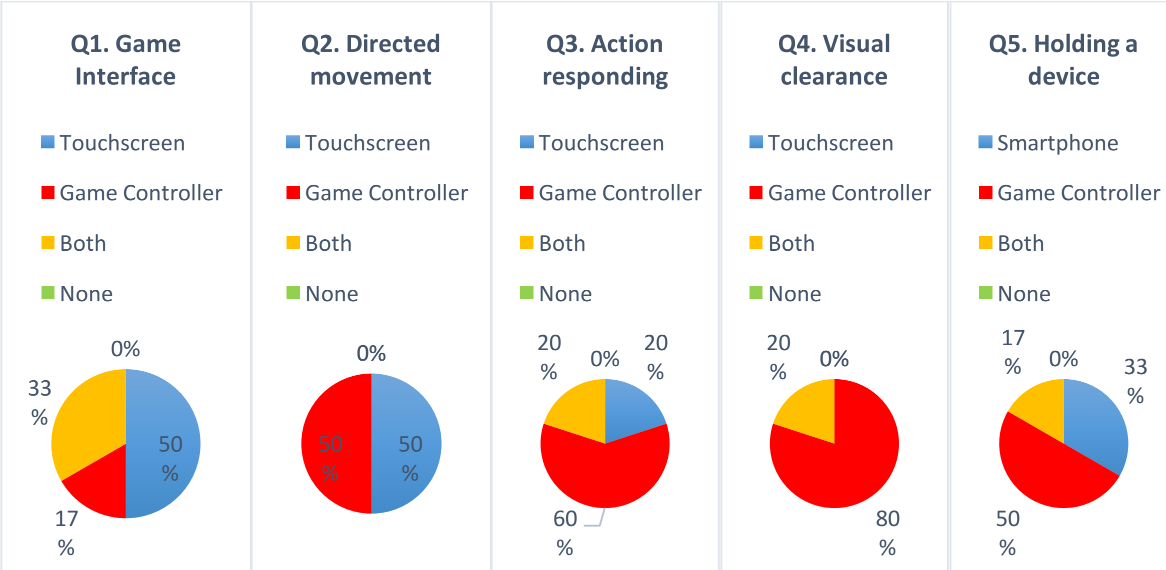


Figure III-12. Comparisons for comfortable level between touchscreen and a game controller

- According to the preference for the game interface control between touchscreen and a game controller, the touchscreen was ranked 88%, 4% for a game controller and 8% for both touchscreen and a game controller.
- According to the preference for the directed movement control, touchscreen, and a game controller were equally ranked as 50%.
- According to the preference for the action control between a touchscreen and a game controller, the touchscreen was ranked 20%, 60% for a game controller and 20% for both touchscreen and a game controller.
- According to the preference for visual clearance on the screen between touchscreen and a game controller, the touchscreen was ranked 20% and 80% for a game controller.
- According to the preference for holding a device between a smartphone and a game controller, the smartphone was ranked 33%, 50% for a game controller and 17% for both touchscreen and a game controller.

Summary of findings

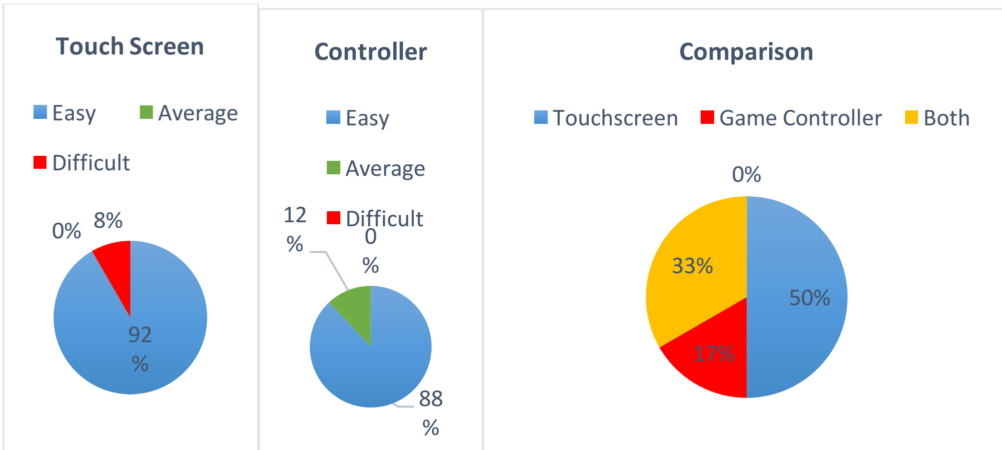


Figure III-13. Q1: Analysis of preference for the game interface

- According to the evaluation for the comfortable level of game interface control, both touchscreen and controller were positive over 90% of participants' responses. However, the result of preference in a comparison between the touchscreen and a game controller was ranked as only 17% for a game controller. 33% of participants responded that both conditions were preferred. This result reflects the preference of overall user experiences as being more positive with playing a game on the touchscreen. <u>In terms of these findings for the hypothesis in this study, further studies with different conditions may need for finding more accurate evaluations.</u>

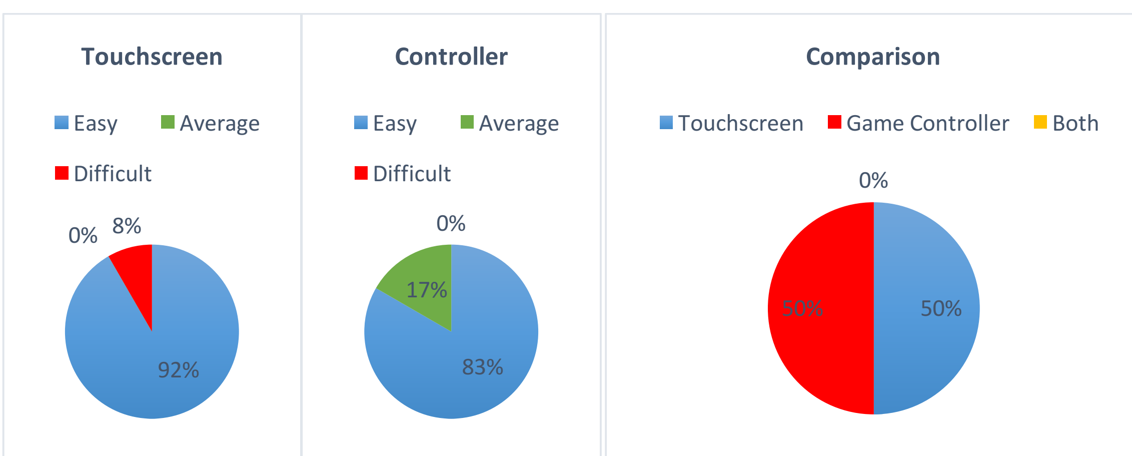


Figure III-14. Q2: Analysis of preference for the directed movement

- According to evaluation for the comfortable level of the directed movement control, 87.5% of participants were positive in preference of both touchscreen and controller. However, the result of the comparison between two tasks was equally divided between touchscreen and a game controller. This result can be different if the question was asked for each game since the result for the 'Time Length for User Achievement on Each Participant' was positive. Further studies may need to demonstrate more accurate measurement for this evaluation.

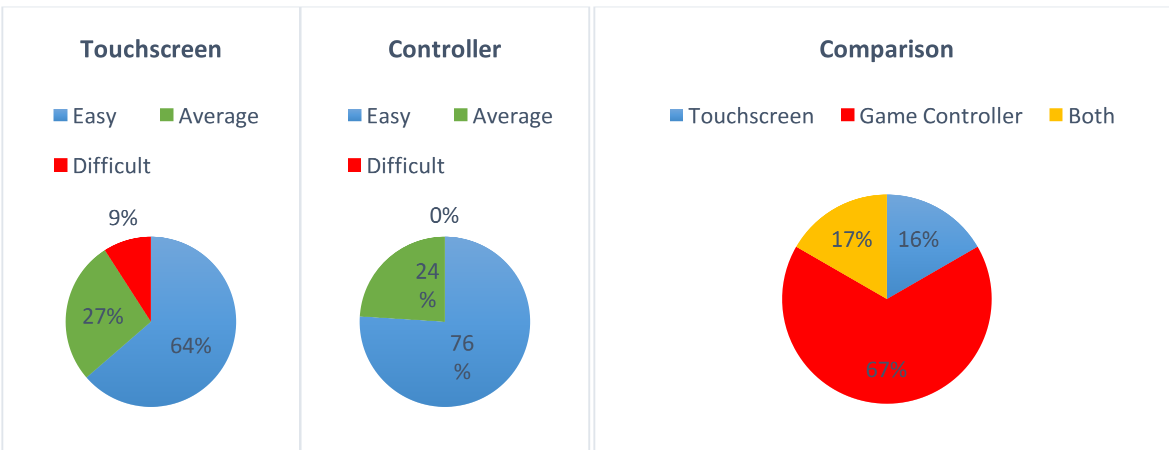


Figure III-15. Q3: Analysis of preference for the control actions

- According to evaluation for the comfortable level of the control actions such as jumping and shooting, 70% of participants were positive in preference of both touchscreen and controller. However, the result of the comparison between two tasks was different as 67% for the game controller, 17% for touchscreen and 17% for both conditions. This result reflects that participants played better when they use a game controller for Game B which requires both control actions and movement.

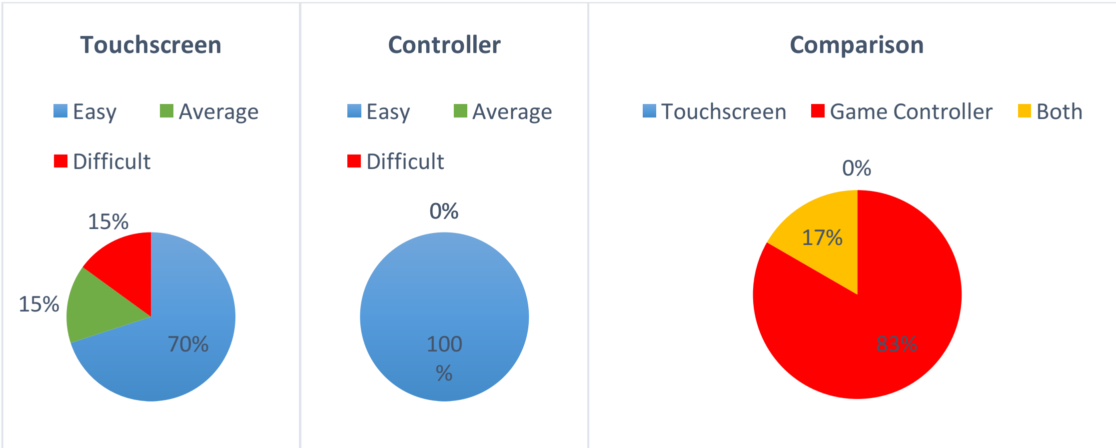


Figure III-16. Q4: Analysis of preference for the visual clearance

- According to evaluation for the comfortable level of the visual clearance for seeing the screen while they were playing a game, 85% of participants were positive in preference of both touchscreen and controller. However, the result of the comparison between two tasks was different as 83% for the game controller and 17% for both conditions. <u>This result reflects that participants see the screen better when they use a game controller. However, if the task is given by using a touch pen, the result of this evaluation can be different.</u>

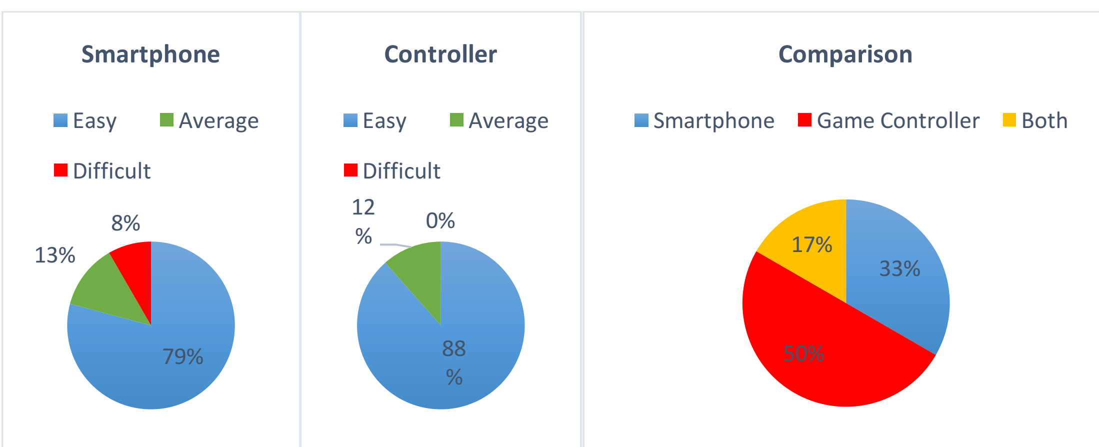


Figure III-17. Q5: Analysis of preference for holding a device

- According to evaluation for the comfortable level of holding a device while they were playing a game, 83.5% of participants were positive in preference of both smartphone and controller. However, the result of the comparison between two tasks was different as 50% for the game controller, 33% for the smartphone, and 17% for both conditions. This result reflects that participants do not have any significant issues or problems holding a device since individual comfortable level does not appear any negative responses.

3.2.4. Analysis of Open-ended Survey

There were ten questions for the open-ended survey. Each participant took a note on the survey sheet and stated additional comments through verbal conversation with the PI. All participants had prior experiences of playing games similar to A, B, or C. Only one participant had experience with it through smartphone game, and other participants played similar games through either video and/or PC platform. Based on the responses, participants' behaviors such as physical gestures and verbal reactions were reviewed and considered for additional evaluations for this study.

Questions:

1) Have you played any games similar to A, B, or C? If yes, what platform was your experience (PC, Smartphone, Video game, etc.)?
2) Have you experienced playing any games with game controllers? If yes, what type of game controller(s) was it?
3) Which game was the most comfortable to play on the touchscreen? And why?
4) Which game was the most frustrating to play on the touchscreen? And why?
5) Which game was the most comfortable to play with the game controller? And why?
6) Which game was the most frustrating to play with the game controller? And why?

7) What did you like most about playing a game on the touchscreen?

8) What did you like most about playing a game on the game controller?

9) What did you find most frustrating about using the touchscreen?

10) What did you find most frustrating about using the game controller?

Summary of findings

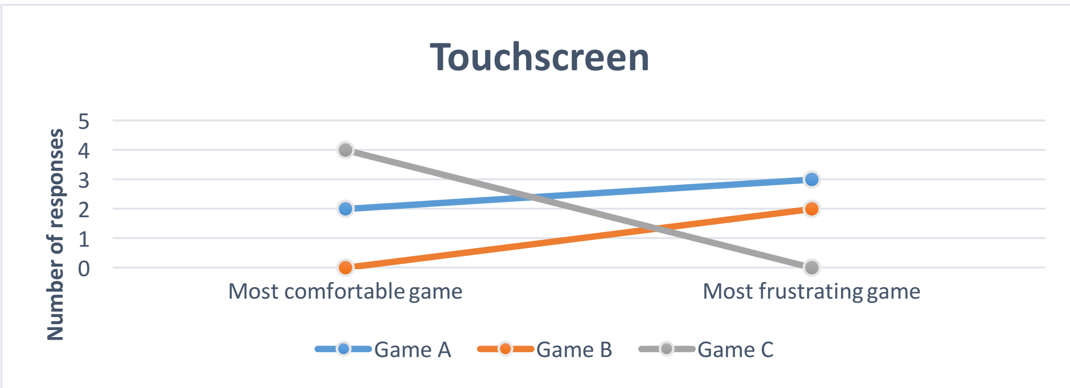


Figure III-18. Comfortable level on touchscreen

Most Comfortable:

- AirAttack (Game C) was the most comfortable game to play on touchscreen. Participants responded that the game control was so easy since the only movement was the main focused tool to play the game. Input control responded much faster on a touchscreen so that participants were holding a finger and kept moving the airplane on the screen.
- PacMan (Game A) was also comfortable among the games on the touchscreen. One of the responses for this reason was that using a finger touch was easier to control the direction that PacMan was moving. This result corresponds to the game achievement based on the time-length that participants played the game with touchscreen longer than using a game controller.

Most Frustrated:

- PacMan (Game A): A PacMan was small and being covered by a finger. Also, it was hard to grab it and change the direction.
- Meganoid (Game B) was difficult to control two actions at the same time, and jumping was not easy due to a lack of tactile responding.

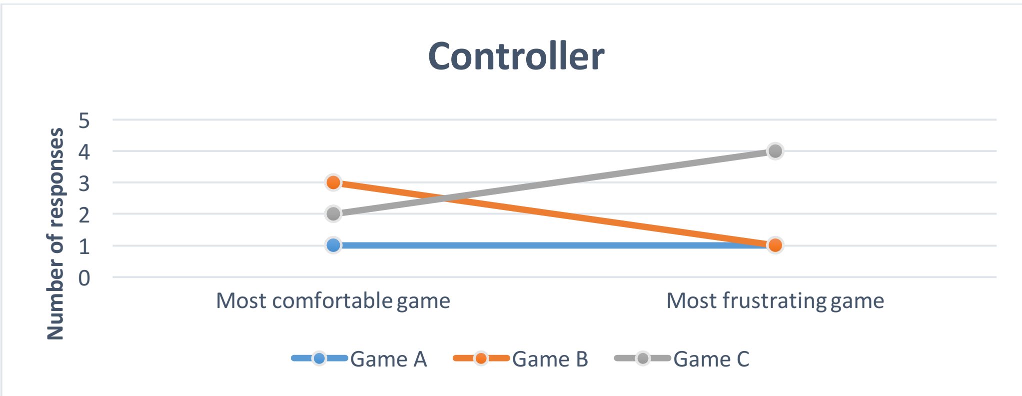


Figure III-19. Comfortable level on game controller

Most Comfortable:

- Meganoid (Game B) was easy to control compared to a touchscreen, especially jumping was efficient to control while direction movement was navigating.
- AirAttack (Game C): A joystick control was very responsive, and the screen was clear to see the airplane track.

Most Frustrated:

- AirAttack (Game C): The airplane was not moving directly that some player wanted, especially diagonal parabolic direction that touchscreen allowed users to move any point in space. It was difficult and not comfortable to determine spatial movement compared to a touchscreen.

3.2.5. Other findings

PROS on touchscreen:

- easier to tap,
- more hands-on and movement was much more direct for most games,
- fast responding,
- easy to see/focus everything on the screen,
- more control and flexible for hands/finger relax.

CONS on touchscreen:

- covering the screen,
- a lack of tactile responding,
- required lot of action with figure movement on the screen,
- not easy to hold a phone and playing two control buttons (left-right).

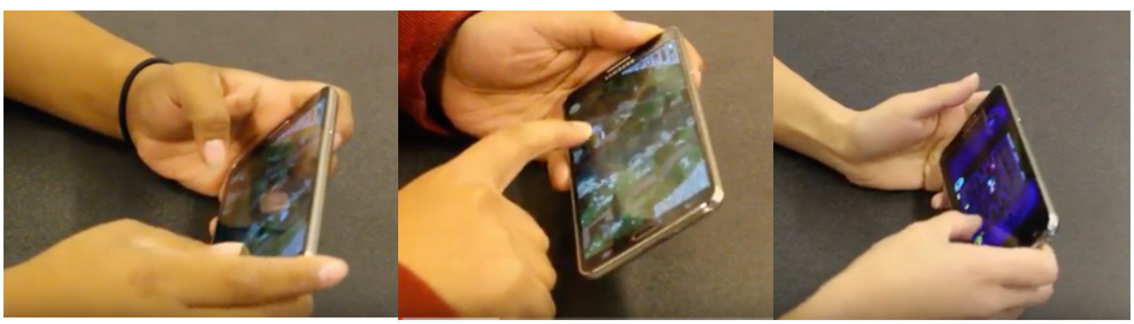


Figure III-20. Snapshot of playing a game on touchscreen

PROS on the game controller:

- easy to see the entire screen,
- more accommodating to hold the control,
- responsive joystick.

CONS on the game controller:

- The knob was not comfortable to use,
- the lag of the button/movement input to the screen, (Game C),
- would not consider carrying the game controller even if it is more effective and comfortable.

Figure III-21. Snapshot of playing a game on a game controller

3.2.6. Summary of findings from the usability test on Pilot Study

According to the evaluation of the result from the pilot study, this study found that touchscreen was more effective with playing a game as directed input control task and multi-input control tasks with a game controller. However, the touchscreen was more effective and easier to control a single input control, especially continued the movement for sticking/tapping/swiping finger gestures on the touchscreen showed the most effective circumstance in smartphone game environment. Even though most participants' responses were positive with touchscreen through Game A and C, preferences in comparison were not absolute positive with touchscreen only. Control movement and action tasks in the comparison between touchscreen and a game controller appeared equally by the usability test and exit survey. According to the evaluation of the result from the pilot study intended to find effectiveness, accuracy and comfortable level between touchscreen and a game controller, there are few considerations to further studies.

a. <u>Universal input control system needs to consider for the game controller:</u> A game controller is limited to play games in terms of emulating issues by the game controller providers. This restricted functionality allows smartphone users to play only limited games.

b. <u>A new product design for a smartphone may introduce different options for game user-friendly:</u> Smartphone case design can be customized in terms of user's preference or built-in input control tool can be considered as a new product design for a smartphone.

c. <u>Smartphone game design should consider more enhanced touchscreen input control in user interaction:</u> If smartphone games are typically developed for touchscreen input control in user interaction, why does the third party developer provide a game controller? This question is similar to a case that some users prefer to use the touch pen for tablet PC.

d. <u>User interface guidelines for smartphone should be considered to increase a satisfaction of enjoyment and comfortable level,</u> e.g., interface design (shape, size, color and position) and number of input controls: According to the result of participants' demonstration for the Game B, smartphone games required multi-input control tasks are not satisfied with comfortable level, enjoyment, and engagement for playing a game on touchscreen.

Figure III-22. A pair of mini joystick -'The Fling Mini'(Robot Check)

Figure III-23. A virtual analog stick controller (Robot Check)

- These two examples are attachable joysticks for smartphone screen of which users can play the game with a built-in virtual graphic interface. This controller provides analog feeling while users interact with virtual input control on the screen. This type of controller might be more effective to interact a single task for each side.

3.3. Proposal for the Main Study

According to the lack of empirical evidence comparing between digital and analog interface on a smartphone, the research question for this study was whether touchscreen gaming with/without a virtual interface for input control interaction is more effective since all analog input controller has transformed as digital touch sensor in smartphones. The hypothesis regarding research subject was that *"If smartphone users were experienced with a digital touchscreen interface, they would have a positive experience through playing a smartphone game on a touchscreen as well."*

In terms of analysis of the usability test in the pilot study, the result of the evaluation of participants' responses was positive for touchscreen gaming within a single input control (Game A and C), especially Game C was the most effective touchscreen gaming. For multi-input task games (Game B) was the most frustrating game among the participants. Thus, the main study will focus on different conditions for touchscreen gaming on a single input control within arcade games which are similar to Game A and C.

The main study will be comprised of various groups for collecting values and data in comparison of different conditions between touchscreen and touch pen. Samsung Galaxy Note series are the only one device on the market that provides a built-in touch pen. This main study intends to find the effectiveness of a new touchscreen gaming console for smartphone game users, in addition to discovering effective gaming environment of user interaction, so finding results and evaluations would reflect to game developers and smartphone manufacture companies to consider a new smartphone design in the future. The main study will be evaluated with several other games which gaming control methods are similar with Game A and C. Comparison of different type of games would appear user's satisfactory level as to discover what type of games would be more effective with a touchscreen versus a built-in game controller. These findings will bring significant concerns for game developers, and this study will also claim the problems and issues for smartphone game industry that a couple of thousand games reveals every year without significant consideration of touchscreen gaming environment.

CHAPTER IV. A MAIN STUDY OF THE TOUCHSCREEN USABILITY

According to the analysis of the usability test in the pilot study, the result of the evaluation of participants' responses appeared positively that a single input control task with a finger tap of one hand in Game A and C was useful in smartphone gaming environment. Game B appeared as the most frustrating game concerning difficulty with two hands for multi-input control task. However, all participants performed Game B much longer with using a game controller than when they played it with a touchscreen. This result underpins that multi-input control games on a smartphone are not effective for game achievement. The pilot study endorsed that using a gaming controller would not be adequate if a smartphone game was not designed with consideration of the interactive platform for the touchscreen input control interface. Thus, this study intended to expand usability test with larger number of groups for finding comfortable level, effectiveness and accuracy based on given touchscreen condition with different input control tasks as following questions;

- Which type of game is more efficient for touchscreen or a built-in controller? (Comfort level of the control input interface)
- Which interaction between touchscreen and a built-in controller is more dynamic and speedy? (Effectiveness of dynamic interaction)
- Which interaction between touchscreen and a built-in controller is more accurate to the achievement of the game level? (Accuracy of responsive interaction with given input control tasks)

The purpose of the main study is to find how smartphone users would be satisfied with using a touchscreen controller while they are playing a game which requires shooting and movement of the object. According to Saffer (2008) in a demonstration of finger gestures between one and two hands for a touchscreen interface, this study compares satisfactory level from two different input control tasks: touchscreen interface itself versus built-in controller which is interactive with a virtual interface on the touchscreen. The collected data from implementation of the usability test by each user were analyzed by a statistical configuration in descriptive individual and correlation of the group.

4.1. METHOD OF USABILITY TEST

The primary objectives of the main study are fundamental to discover the effectiveness of input control interaction for smartphone gaming environment. Through reviewing the related works in literature in which *"Direct Manipulation Interface"* was focused (Hutchins, Hollan, & Morman, 1985), the usability test was comprised of nine tasks for collecting values and data in comparison of different conditions with input task controls between finger touch and physical touch controller. Also, the primary study compares two games required to interact with input control interface by one hand or two hands' control (Saffer, 2008) and effectiveness between touch-based and analog input control (Zaman, Natapov and Teather, 2010). Two different games were divided into two groups, and each group will focus on one input control task. Four groups implemented playing a game with physical controllers applied: built-in touch pen replacing a finger touch and joypad controlling a virtual graphic interface. These groups were observed as how they control input system with a finger(s) touch and a game controller. Control performance by users was also observed during a task to find how users make errors or mistakes in terms of interface design in both digital and analog controls.

4.1.1. Description of Procedure

For the main study of the usability test, the Iowa State University Internal Review Board (IRB) requirements were met, and the revised IRB form for the main study approved to utilize human subjects on March 16, 2016. All revised and approved IRB documents can be found in the appendix. The usability test took place at the University of Nevada, Las Vegas campus. A usability test was conducted with a total of 81 participants who agreed to be part of the human subjects for the main study. All participants were recruited by the PI's contact by word of mouth and flyers around campus. The following lists are a summary of the statement of the procedure of the usability test.

1) The researcher contacted prospective participants to schedule a usability study from both word of mouth and flyers at the University of Nevada, Las Vegas campus during March 2016.
2) Any potential participant who informed his/her interest in the usability test, PI verified with them through the email.
3) On the selected date of the usability study, each participant was given a copy of the Informed Consent Document for review and to sign before the start of the session.
4) Before the session, each participant was informed of information regarding the purpose of study and game instruction for the implementation of the usability test.
5) Before the beginning of the usability test, each participant completed the pre-survey questionnaire regarding demographic information and their familiarity with the technologies.
6) The usability testing took place at GRA 241 at University of Nevada Las Vegas. All test activity from each participant was recorded as voice and/or video during the test.

Participants' hand(s) and finger(s) movement was also recorded while playing a game. Participants will not be identified in any future video use (i.e. video will not include face).

7) The participants performed a series of tasks on the interface design of playing a smartphone game. They may skip any tasks if they do not wish to perform or that makes a participant feel uncomfortable.
8) All participants completed a brief exit survey and interview after the usability testing.

4.1.2. Game Information

For evaluating user interface between touch-based and analog control in gameplay, the test was comprised of playing two different casual shooting games. The previous works adopted the tasks; using the touchscreen to shift (Vogel and Baudisch, 2007), rubbing and tapping (Olwal et al., 2008), and finger orientation (Wang et al., 2009). Two games were selected for evaluating input usability for the single and multi-input control interaction compared with touchscreen and built-in game controller; this test was comprised of playing two different casual shooting games. These selected games were reviewed as smartphone game-environment-friendly in terms of touchscreen-based driven. Each game was chosen by consideration for users who may be familiar with common game rules from their experiences. Games are comprised of different input tasks; movement by one hand (automatic shooting but occasional bombing with button) and movement and shooting by two hands.

Testing Games

There are nine groups to conduct two different genres of smartphone games. Each group was assigned one of these games with various input control tasks. This study experimented with an action displayed on the screen; selecting and changing the subject's orientation on the screen. Oshita and Ishikawa (2012) also demonstrated a comparison of action section for a user interface of the computer game to provide a guideline for choosing and designing interfaces. The following two games were selected to evaluate comfortable level, effectiveness, and accuracy between one and two hands' control.

Game D: iFighter 1945 (Movement & occasional bombing)

'iFigher 1945' is a simulation of the air battle which is similar with 'AirAttack' in the Pilot Study. The basic game rule is to avoid enemies' shooting at the same time killing enemy's group in both ground and air. This game is to achieve the game level with obtaining points from shooting targets and taking tokens. The game difficulty level for the usability test will be set as normal that player is moving towards a harder level. Input control task is a primary movement by one hand control with automatic shooting, but a player can use an occasional bomb when the player wants to escape from chaos with many attacks. An icon of Bomb is located on the right side as a red button. This function can be used up to three times during a game if participants need to avoid heavy attacks from the enemies. If a participant does not use a bomb, each saved bomb will be credited back to 5000 points per each one in the total score at the end of the game. Since this game provides only one chance (a single opportunity) to play a game, the time length of the gameplay will be measured. Other data in total score including obtained tokens and the number of kills will be identified at the end, and this data will be analyzed as part of the evaluation. Once the enemy was killed, it is changed as an item to obtain points. This game provides two different input controls for direction and movement: figure gesture on a touchscreen and virtual graphic touchpad control (Figure IV-1). The airplane shooting can be set up either automatic or manual control through the game option.

* *Touchscreen* * *Touchpad*

Figure IV-1. iFighter game screen snapshot

Game F: Tank Hero (Movement & Shooting)

Tank Hero is another simulation game of the battle which is required to establish game strategies regarding difficulty of a provided map and the number of target enemies. This game is to achieve the game level with obtaining points from shooting targets. The game level is arranged with 1- 40 and the usability test will begin with level 1. The input control task is a primarily movement and target shooting with two hand control. The basic game rule is to avoid enemies' shooting at the same time killing target tanks. The shooting requires measuring the angle to hit the target with touch control in which a player can easily tap any space or target to kill the enemy. This game provides three (3) opportunities to play the game and the time length of the gameplay will be measured. Other data in total score will be identified at the end, and this data will be analyzed as part of the evaluation. This game also provides two different input controls for direction and movement: figure gesture on a touchscreen and virtual graphic touchpad control (Figure IV-2). Shooting is anywhere a user touches on the screen.

** Touchscreen* ** Touchpad*

Figure IV-2. Tank Hero game screen snapshot

Game Controller

For finding a comparison with efficiency and accuracy in satisfactory level from a game on the touchscreen, the usability test is comprised of using a physical game controller to interact with touchscreen for input control. A few groups were assigned to use a physical game controller instead of using a finger on a touchscreen. There are two different controllers selected in terms of the assigned game environment that movement control was discussed with either direct or indirect responses by users as how they perceive graphic information simultaneously with movement and direction. For one of the analog controller, Samsung provides a built-in "S-Pen," that a smartphone user can touch and write on the screen (Figure IV-3). According to the small point tip of the pencil style, this controller may be easier and more accurate to control an object on the screen.

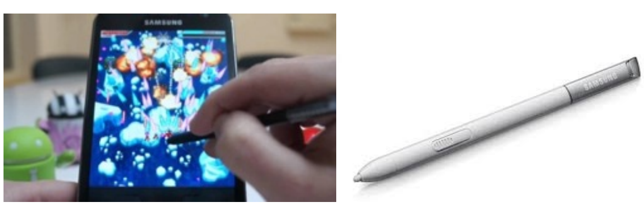


Figure IV-3. Built-in analog controller of Samsung Galaxy Note *(S-Pen)*

The second analog control is called "SmartTACT," which interacts with a virtual joypad on the screen. This joypad is designed as a thin round shape to be attached to the top of the virtual control on the smartphone screen. This control allows users to use a thumb for moving around 360-degree angles, and it may be easier to control the movement on the static interface on the side of the smartphone (Figure IV-4).

Figure IV-4. A Virtual Analog Stick Controller *(*SmartTACT[45])*

4.1.3. Implementation of Usability Test

As consideration of the purpose of the usability test to measure the quality-in-use of interactive computer usages (Bevan, 1995), the usability test was arranged by tasks achieved with effectiveness, efficiency, and satisfactions by participants. A total of 81 participants implemented usability test for the main study. According to an approach of finding the difference between two variables with one and two hands interaction, there were two big groups divided for different games. Nine groups were divided concerning distinctive conditions of playing the game, and each group was comprised of nine participants regardless of gender, age or prior experiences. Each participant spent approximately 30 minutes except Group E-1, which requires a pre-exercise before participants conduct the usability test. For the collection of data from the implementation of the usability test, the game tasks and guidelines were created based on findings of a satisfactory level: Comfortable level of the control input interface, Effectiveness of dynamic interaction and Accuracy of responsive interaction with given input control tasks. During the usability test, participants' performances were recorded by audio and video for analyzing user's behavior, finger/hands gesture, and a reaction of the game tasks. According to Hornbaek and Law (2007), the measurement and

[45] http://www.amazon.com/SmartTACT-Smartphone-Controller-Joystick-Emulators/dp/B010OWPFHQ

evaluation of usability test in user experience (UX) and user interface (UI) varies with subjects beyond quantitative values. For the method of the assessment of quality in usability, participants' performances were recorded by audio and video for analyzing user's behavior, finger/hands gesture, and a reaction of the game tasks During the usability test.

Tasks and Guidelines for playing a game

The following are the list of guidelines for Group A, B, C and D. Nine participants on each group conducted by the assigned condition. Each participant played the game, "iFighter 1945" with a single input control interface. Figure IV-5 shows a graphic information of the different condition of playing a game per each group. All participants were asked to play a game by using one hand. According to the assigned usability test condition for each group differently, it is critical to observe how each participant interact with an input control to achieve the goal effectively.

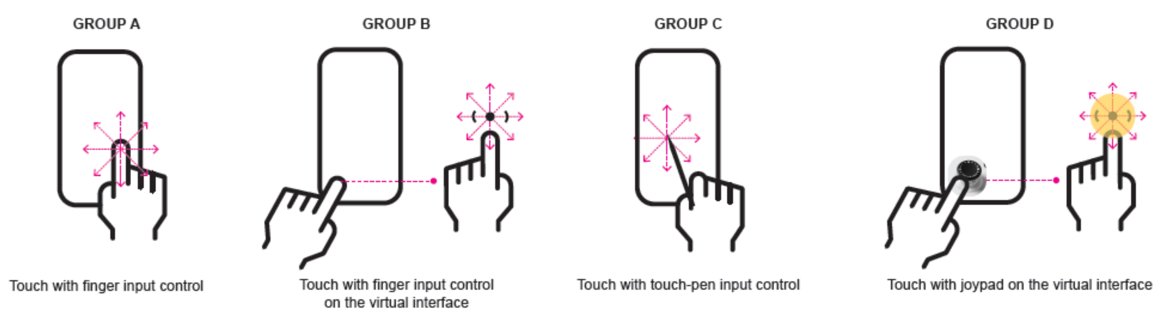


Figure IV-5. Tasks condition of the one hand interaction

- Group A: iFighter 1945 (Touch with input finger control)

  This group requires a game task and rule to play a game by using a finger to control movement and direction of the airplane. Users may use right or left finger to interact with the touchscreen while they are holding a smartphone with the other hand.

- Group B: iFighter 1945 (Touch with input finger control on the virtual interface)

This group controls a movement of direction and position with a virtual control on the left bottom of the screen.

- Group C: iFighter 1945 (Touch with touch pen input control)

  Participants in this group are asked to use "S-pen" to control movement for both direction and position. The performance is still on a touchscreen with an analog control instead of using a finger same as Group A.

- Group D: iFighter 1945 (Touch with joypad on the virtual interface)

  This group performs playing a game with a virtual analog stick controller on the top of the virtual interface on the same condition of the Group B.

The second groups (E, E-1, F, G, and H) conduct playing a game with a multi-input control interface. This game requires two input tasks simultaneously to achieve the goal of killing target enemies on each level. However, the Group (E-1) conducts playing the same game as the Group E. Participants in this group are allowed to have pre-exercise for 15 minutes before they perform the actual test. The result of usability test compares with Group E in which participants conduct a task for touch with input finger control. This method is to find differences between these two groups as how participants in each group approach the game strategy and interaction regarding prior experiences with given game. Finding results from these two groups become a standard methodology to further steps for the assessment tool of the variable data. Figure IV-6 addresses different tasks with four different input control conditions.

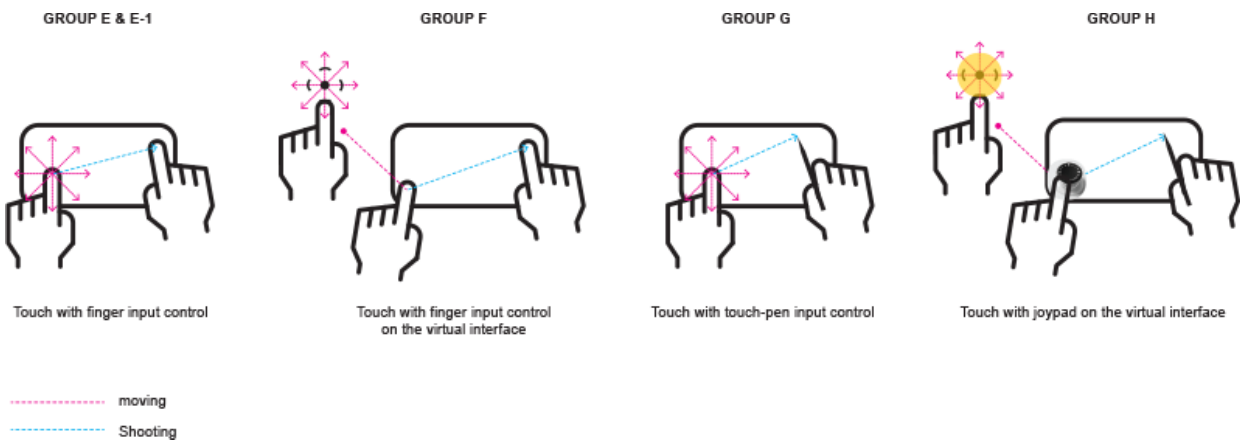


Figure IV-6. Tasks condition of the two hands interaction

- Group E & E-1: Tank Hero (Touch with input finger control)

  This group requires a game task and rule to play a game by using two hands to control movement and shooting at the same time. There is no left or right control between a movement of shooting. This input control task is designed by finger gesture with no control interface on the screen. Dragging the tank from one to the other space with finger gesture makes a tank movement. A shooting tap from anywhere on the screen is a fire from the current position of the tank to targeting the enemy.

- Group F: Tank Hero (Touch with input finger control on the virtual interface)

  Participants in this group will have a virtual control on the bottom of right side of the screen. The virtual joypad allows users to move and change the direction of the tank while shooting is the same method of tapping to the target on the screen.

- Group G: Tank Hero (Touch with finger and touch pen input control)

  This group is set up with the same environment as Group E. However, participants control movement with finger touch without the virtual input control, but shooting to the target with the "S-pen." This task is to find if using a touch pen would be more accurate to fire the target when more than one target tries to attack. However, the touch pen can be considered as each participant's preference whether she/he prefers to using it as movement or shooting.

- Group H: Tank Hero (Touch with joypad and touch-pen on the virtual interface)

  Participants in this group use only a physical controller attached on the screen. The joypad was located on the top of the virtual control interface, and the fire is used by the touch pen. All participants are obligated with using these tools as nature of the function with each physical condition.

Statement for Conducting Usability Test

PI began with recruiting participants once the committee approved the revised IRB on March 16, 2016. During the month, PI has received over 30 potential participants who were full-time students taking any art and design courses at University of Nevada Las Vegas. Recruitment continued until in the middle of April to reach the 90 participants. After confirmation for meeting schedule through email, each participant visited PI's office to conduct the usability test. Once a participant arrives, PI took a couple of minutes to accommodate a participant for being comfortable and awareness of the purpose of this study. Most participants were very interested in knowing about this study, and this introductory greeting helped them to perceive the importance of their tasks and performance. Once the usability test began, the video and audio were recorded for observing hand(s) and finger(s) gesture. During a task, PI also kept observing other performance of each participant such as facial expression, body movement, and any side effect of frustrations from playing a game. Each participant completed the game, the total score and time length were collected on a separate sheet. During the open-ended survey, PI spent more time for discussion of further questions if necessary with participant's agreement.

Exit Surveys

Survey questionnaires are typically used for evaluating satisfactory which influences the effectiveness of usability. According to Choe and Shcumacher (2015), this study developed contexts to find perceived usefulness, ease of use, enjoyment, and cognitive concentration. In terms of different tasks on each game, the exit survey was comprised of two separate questionnaires. For the first groups A-D, questions are related to the single input control in movement. Survey questions in the second groups E-H were arranged with the multi-input control with movement and shooting. Open-ended survey questions were collected from both the participant's written statement and dialogue with the PI. All answers were summarized for analysis of the exit survey and game score in correlations.

Table IV-1. Exit Survey for Group A-D

	Questions		1	2	3	4	5	
1.	Overall, how easy was it to change directions?	Easy						Difficult
2.	Overall, how easy was it to change movements?	Easy						Difficult
3.	Overall, how easy was it to see contents on the screen while you are controlling interfaces?	Easy						Difficult
4.	Overall, how comfortable was it to hold a smartphone during a playing a game?	Comfort						Discomfort

Table IV-2. Exit Survey for Group E-H

	Questions		1	2	3	4	5	
1.	Overall, how easy was it to change directions?	Easy						Difficult
2.	Overall, how easy was it to change movements?	Easy						Difficult
3.	Overall, how easy was it to see contents on the screen while you are controlling interfaces?	Easy						Difficult
4.	Overall, how easy was it to aim the target in shooting?	Easy						Difficult
5.	Overall, how easy was it to control both movement and shooting at the same time?	Easy						Difficult
6.	Overall, how comfortable was it to hold a smartphone during a playing a game?	Comfort						Discomfort

Open-ended Questions

1) What did you like most about input control tasks during gameplay? Why?

2) What did you find most frustrating about input control tasks during gameplay? Why?
3) Have you ever used any physical controller for smartphone games? If yes, what was it? Why did you use it?
4) Are you willing to use a physical controller for smartphone games? Why?
5) Do you perceive any different input control reaction between arcade and smartphone game environment (e.g., input control, comfortable level, achievement difficulty, playing methods, etc.)?
6) What strategy did you find to achieve a better game level?

4.2. Results and Findings of Main Study

4.2.1. Method of Data Analysis

Evaluation of the result of the usability test is usually analyzed with a game score and time length (MacKenzie, 2010; Pereira & Roque, 2013; Ruy,2010). Moreover, Hornbaek and Law (2007) investigated 73 studies to provide information about how to select measures of usability to look at correlations between usability measures. According to 180 studies reviewed by Hornbaek (2005), most articles adopted an ANOVA test to analyze correlation values between independent usability variables of the achievement level in gameplay. With game score and survey data from each participant in the usability test, all data was analyzed by using *"JASP"* statistic program which provides a descriptive and an ANOVA test. All collected data was transferred into Excel table to assert each category for the configuration of a data set. The following addresses the result of analysis for each category of the statistical data.

4.2.2. Analysis of Demographic

Demographic information was collected by the survey. There was a total of 81 participants comprised of 44 females and 37 males (Table IV-3). The participants' age ranged between 18 - 41 years old. Table IV-4 shows data which indicates a different age group: 1 (18-23), 2 (24-29), 3 (30-35) and 4 (36-41). Over 50 participants were in an age group between 18-23. According to demographic of participants as college students, all participants answered that using computer devices is comfortable, and they use either Apple or Android smartphone.

Table IV-3. Frequencies for gender

	Frequency	Percent	Valid Percent	Cumulative Percent
F	44	54.3	54.3	54.3
M	37	45.7	45.7	100.0
Total	81	100.0	100.0	

Table IV-4. Frequencies for age

	Frequency	Percent	Valid Percent	Cumulative Percent
1	54	66.7	66.7	66.7
2	20	24.7	24.7	91.4
3	2	2.5	2.5	93.8
4	5	6.2	6.2	100.0
Total	81	100.0	100.0	

**Note: 1 (18-23), 2 (24-29), 3 (30-35), 4 (36-41)*

Figure IV-7 addresses a descriptive statistic for participants' prior experience with computer usage and frequency of playing a game through different computer devices such as Smartphone, Tablet, and Video/PC. A total of 78 participants use a computer daily, but only 34.6 percent (28 participants) played a smartphone game daily. Eight participants were not experienced with a smartphone game, but they have played either video or PC game.

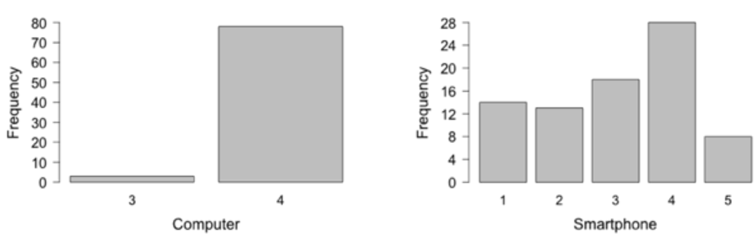
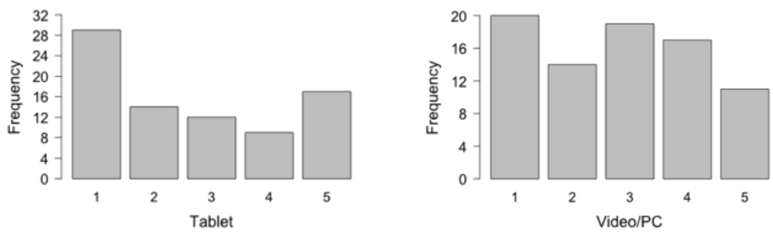


Figure IV-7. Arrange of computer usage



** Experience with computer devices: V= 1 (Less than Monthly), 2 (Monthly), 3 (Weekly), 4 (Daily), 5 (Never)*

Figure IV-7. continued

4.2.3. Result of Usability Test

With the completion of given task of the usability test by each participant, the data was collected by automatically generated game score at the end of a game (Table IV-5 and IV-6). Total score in Groups A-D was calculated by item scores (Silver & Gold star), killed score, and bomb. Gold and Silver stars were obtained by items converted by any target fired or killed on the air and ground. Group C and D showed higher scores than Group A and B. This result addresses that the game achievement was better when participants were using an analog input control device on the top of the touch screen.

The score of the Bomb obtained a full score of 15000 points when a participant did not use it at all, but it recorded with ‘0’ point from total usage. Only eleven participants of the total 36 participants in Groups A-D used all three bombs. Killed points were obtained by shooting targets. However, this score was not effected to the game achievement with time-length of playing a game. For analysis of the result of a usability test, descriptive data values were analyzed per each group to find the mean and median values. Correlation values were analyzed between each group to compare which group would be more satisfied and effective with using an input control in the given condition.

Table IV-5. Collected data for the game score on Group A-D

Player	Gender	Silver star	Gold star	Killed	Bomb	Time	Total Score
Group A: iFighter 1945 (Touch with finger input control)							
A1	F	8250	10500	42100	15000	1.20min	88850
A2	M	2750	2100	57300	10000	1.48min	73150
A3	F	13500	10500	39500	10000	1.53min	75500
A4	F	5500	2800	47900	15000	1.47min	72200
A5	F	7000	3500	60800	10000	1.59min	85600
A6	M	9750	7700	56800	15000	1.38min	96250
A7	F	7750	6300	28200	15000	1.28min	59250
A8	M	13250	10500	84400	0	3.52min	118150
A9	F	5750	3500	18500	15000	1.04min	44750
Group B: iFighter 1945 (Touch with finger input control on the virtual interface)							
B1	M	12500	9800	98600	15000	1.33min	140200
B2	M	5250	2100	35100	15000	1.36min	58450
B3	M	4750	4200	4000	0	2.16min	96150
B4	M	6500	4900	76500	0	1.55min	92200
B5	F	3250	4200	31700	10000	1.29min	60150
B6	M	4250	2800	28500	15000	1.06min	64850
B7	F	3000	2100	30100	5000	1.43min	40500
B8	M	15250	14000	78700	5000	3.28min	127250
B9	F	2750	700	38800	0	1.34min	42550
Group C: iFighter 1945 (Touch with touch-pen input control)							
C1	F	17500	12600	83500	15000	1.46min	139600
C2	M	7000	8400	52100	5000	1.22min	78500
C3	M	7250	7000	27400	1000	1.07min	54650
C4	F	5000	3500	26300	1000	1.02 min	46800
C5	M	13250	14700	49800	15000	1.38min	105750
C6	M	11500	9800	57500	5000	1.22min	92800
C7	M	37000	34300	211200	0	5.29min	306500
C8	F	14500	7000	66100	0	3.47min	94600
C9	M	32000	32200	174500	0	3.21min	269700
Group D: iFighter 1945 (Touch with joypad on the virtual interface)							
D1	F	5250	1400	29700	10000	1.05min	47350
D2	F	5250	6300	54700	5000	1.35min	77250
D3	M	2000	25900	151900	0	3.09min	221800
D4	F	13250	8400	100200	5000	3.12min	129850
D5	F	7750	5600	47800	0	1.36min	67150
D6	F	7750	4900	356700	5000	2.04min	77350
D7	F	2250	1400	39900	5000	1.29min	49550
D8	M	40250	47600	253300	0	8.34min	369150
D9	M	36750	38500	253250	0	4.54min	364500

Table IV-6. Collected data for the game score on Group E-H

Player	Gender	Time	Level	Accuracy rating	Health rating	Kill rating	Total Score
Group E: Tank Hero (Touch with finger input control)							
E1	F	N/A	5	464	1669	1000	4133
E2	F	N/A	2	342	1000	200	1642
E3	F	N/A	6	672	3668	1300	7141
E4	M	N/A	4	494	2667	800	4561
E5	M	N/A	12	1329	9335	3800	21163
E6	M	N/A	4	1020	2667	700	4987
E7	F	N/A	3	135	1667	300	2402
E8	M	N/A	10	970	6002	3400	15972
E9	F	N/A	4	383	2334	800	4117
Group E-1: Tank Hero (Touch with finger input control) with 15 minutes pre-exercise.							

Table IV-6. continued

E-1-1	F	N/A	19	2835	11335	16300	35470
E-1-2	F	N/A	10	912	8001	3500	16913
E-1-3	M	N/A	12	1025	9335	3900	20988
E-1-4	M	N/A	10	634	8001	2900	14835
E-1-5	M	N/A	17	1672	10668	15900	29762
E-1-6	M	N/A	13	1085	9001	3700	11886
E-1-7	M	N/A	14	2924	11002	13000	25226
E-1-8	M	N/A	22	3065	16002	23500	56582
E-1-9	M	N/A	12	1265	10233	3500	18266
Group F: Tank Hero (Touch with finger input control on the virtual interface)							
F1	F	N/A	4	720	2667	600	4587
F2	F	N/A	5	258	3334	1000	5592
F3	F	N/A	4	166	2667	700	4133
F4	M	N/A	7	837	5001	1700	9638
F5	M	N/A	7	1611	4335	1900	8812
F6	F	N/A	4	470	1668	600	3338
F7	F	N/A	7	1296	5001	1400	9797
F8	F	N/A	5	864	3002	1300	6666
F9	F	N/A	4	462	1335	700	3097
Group G: Tank Hero (Touch with finger and touch-pen input control)							
G1	M	N/A	4	630	2667	800	4697
G2	F	N/A	7	1346	5668	1600	9714
G3	F	N/A	4	365	2334	800	4199
G4	M	N/A	5	970	3001	1000	5971
G5	F	N/A	4	800	2667	600	4817
G6	F	N/A	4	850	2334	700	4484
G7	M	N/A	3	400	1334	300	2334
G8	F	N/A	3	441	1667	400	2808
G9	M	N/A	10	1466	7668	3400	17034
Group H: Tank Hero (Touch with joypad and touch-pen on the virtual interface)							
H1	F	N/A	4	885	2001	700	3252
H2	F	N/A	3	550	1334	400	2584
H3	M	N/A	4	985	2642	900	3756
H4	F	N/A	4	800	1334	600	3334
H5	M	N/A	4	750	1668	600	3618
H6	F	N/A	2	260	667	300	1327
H7	F	N/A	5	404	2668	1100	5172
H8	F	N/A	4	871	2669	1200	4748
H9	F	N/A	4	467	2001	800	3868

4.2.4. Findings of Groups A-D

Groups A-D conducted the game “iFighter 1945” (Figure IV-9). Each participant played the game in different conditions of input control task. According to Figure IV-8, a majority number of participants which is 69.4 percent played the game around 2 minutes, and only one participant played longer than eight minutes. The mean of the total score of the game appeared 1.119e+5 while Standard Deviation showed 8.623e+4 and 2.692e+5 as maximum (Table IV-7).

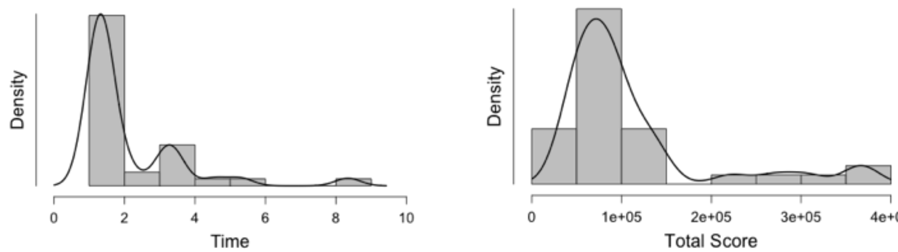


Figure IV-8. Plot arrangement for Time and Total Score

Table IV-7. Descriptive statistics for time and total score

	Time	Total Score
Valid	36	36
Missing	0	0
Mean	2.078	1.119e+5
Std. Deviation	1.511	8.623e+4
Minimum	1.020	4.050e+4
Maximum	8.340	3.692e+5

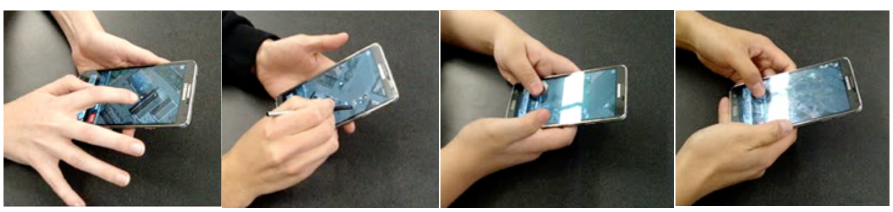


Figure IV-9. Input control tasks in Group A-D

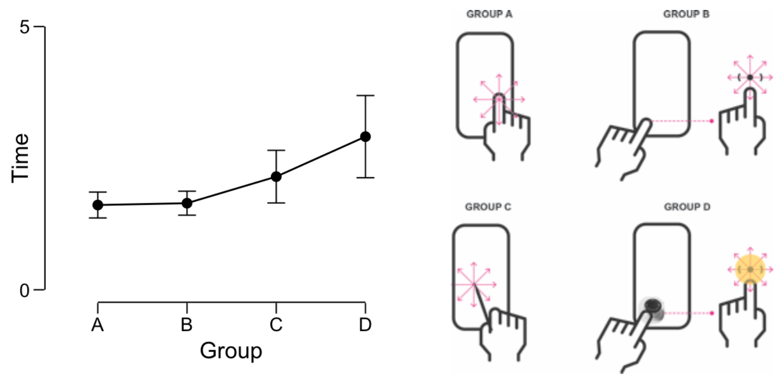
Analysis of Time

Figure IV-10 describes average time length of each group. In a comparison of the mean value, participants in Group C and D played the game longer than Group A and B. Both groups showed the value as larger than 2 minutes (Table IV-8). Moreover, participant 7 in Group C played the game for 5.29 minutes, and participant 8 in Group D played over 8.34 minutes. According to the given input control condition per each group differently, touch-based input control with a joypad on the virtual interface and with a touch-pen was easier for participants. Playing the game with a directed finger touch on the smartphone screen was not efficient for most users in Group A and B.

Table IV-8. Descriptive mean value for time length

Group	Mean	SD	N
A	1.610	0.737	9
B	1.644	0.683	9
C	2.149	1.499	9
D	2.909	2.342	9

**Note: Time (minute)*



**Note: Time (minute)*

Figure IV-10. Plot arrangement for analysis of playing time per each group

In comparison between group and gender for understanding time variable, all values are lower than 95% ($p < 0.05$) which is significantly different effects from each group. This result underpins that this study needs to explore analysis of additional correlations with Marginal Means from the contrasts of these groups (Table IV-9).

Table IV-9. Correlation with group and gender for time variable

Cases	Sum of Squares	Mean Square
Group	18.67	6.224
Gender	12.91	12.912
Group ✻ Gender	15.03	5.009
Residual	42.01	1.500

Note. Type III Sum of Squares

According to the statistical difference contrast between group and gender in Table IV-10, Group D appeared as a significant effect value compared with other groups. This statistic value also addresses that there is a significant effect of gender but, there is no significant difference of time value between Group A and B. Through this finding, input control with an analog controller was more effective for movement control.

Table IV-10. Different Contrast - group and gender for time variable

Comparison	Estimate	Std. Error
B - A	-0.084	0.306
C - A, B	0.151	0.177
D - A, B, C	0.427	0.125
M – F	0.635	0.217

Analysis of Total Score

The total game score was collected at the end of the game automatically. This score was the sum based on the points from the obtained items such as a Silver Star, Gold Star, Killed, and Bomb (Table IV-5). As being similar with significant effectiveness from the analysis of time length, Group D showed the highest score among other groups (Table IV-11). The dependent variable describes the different effectiveness of input control condition between each group. According to the mean value on the Figure IV-11, Group C and D show higher scores, moreover, Group D appears to have a significant difference compared with other groups.

Table IV-11. Descriptive mean value for total score

Group	Mean	SD	N
A	79300	21289	9
B	80256	35910	9
C	132100	93004	9
D	155994	131023	9

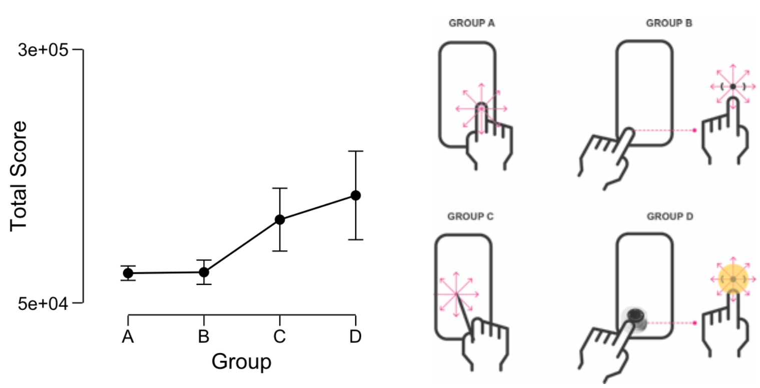


Figure IV-11. Plot arrangement for analysis of total game score per each group

Moreover, there was a significant difference between each group and different gender in correlation. Both gender and group were found that p-value was much smaller than 0.001 and 0.002 for comparison between group and gender (Table IV-12).

Table IV-12. Correlation with group and gender for total game score

Cases	Sum of Squares	Mean Square
Group	7.598e +10	2.533e +10
Gender	7.031e +10	7.031e +10
Group ✻ Gender	6.114e +10	2.038e +10
Residual	8.903e +10	3.179e +9

Note. Type III Sum of Squares

According to the statistical analysis for the difference contrast between group and gender in Table IV-13, Group D appeared to have a significant effectiveness of total score value compared with other groups. However, there is no effective value between Group A and B. Through this finding, input control with an analog controller was more effective for movement control, and this result appeared same as findings of the time length of playing the game. In the exist interview, a majority of participants responded that a lack of tactile control on the touchscreen made a game control difficult to prompt action when it was needed.

Table IV-13. Difference Contrast - group & gender for total score variables

Comparison	Estimate	Std. Error
B - A	-5656	14097
C - A, B	14903	8139
D - A, B, C	25983	5755
M – F	46874	9968

Analysis of Survey Questionnaires

With the completion of the usability test, each participant answered the survey questionnaires. There are four questions that address their experience of a task with the given input control condition. Even though a majority of participants played the game around two minutes, the value of satisfactory level from each question is related to the result of other findings such as total score and time-length of playing the game. Questions were comprised of usability of game controller between finger touchscreen and an analog game control on the touchscreen. The questions are:

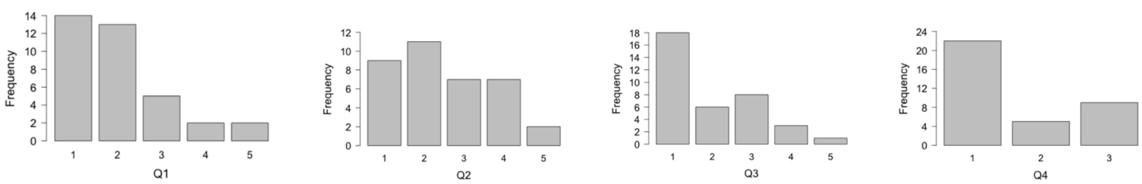
Q1: Overall, how easy was it to change directions?

Q2: Overall, how easy was it to change movements?

Q3: Overall, how easy was it to see contents on the screen while you are controlling interfaces?

Q4: Overall, how comfortable was it to hold a smartphone during a playing a game?

The answers were arranged with 1 as "easiest" and 5 as "the most difficult." Figure IV-12 shows the number of answers from the entire groups. Most users were satisfied with a given control task during a playing of the game, however, a satisfactory level for "Changing Movements" on Question 2 showed less satisfaction in comparison of other performances. In regards to this result, it is necessary to find a detailed analysis of the difference between each group and question.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-12. Result of survey questionnaires

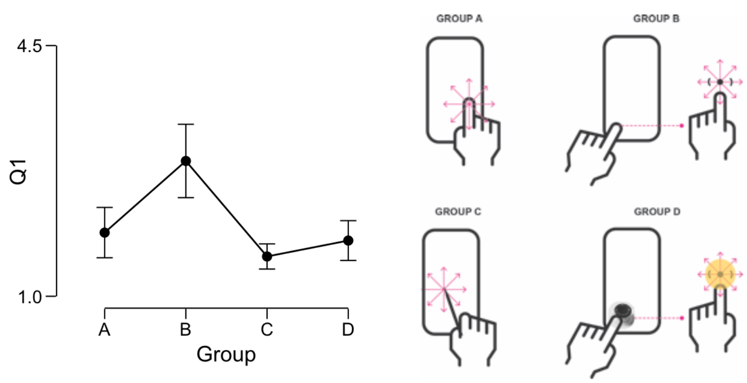
Question 1: *Overall, how easy was it to change directions?*

Q1 was related to finding of satisfactory level for input control in a change of the direction through a short distance. The change of the direction was to obtain an item for the game points. Table IV-14 addresses mean values between groups on the Question 1. The result of the survey shows that Group C and D were most valuable in the satisfactory of control for change a direction. The result underpins that users from these two groups achieved the game level effectively compared with other groups. Most participants in Group A were most satisfied with a finger control for the short distance on the touchscreen. This result reflects that using a finger was not easy to control movement for a short distance regarding the size of the fingertip.

Table IV-14. Descriptive Q1

Group	Mean	SD	N
A	1.889	1.054	9
B	2.889	1.537	9
C	1.556	0.527	9
D	1.778	0.833	9

In comparison between groups, Group B was most ineffective for the satisfactory level of changing direction (Figure IV-13). The analysis of descriptive value on the graph shows that male users are strongly comfortable with an indirect input control rather than a direct input control. Both using a touch pen and joypad were more effective for the change of direction.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-13. Descriptive Plot for Q1

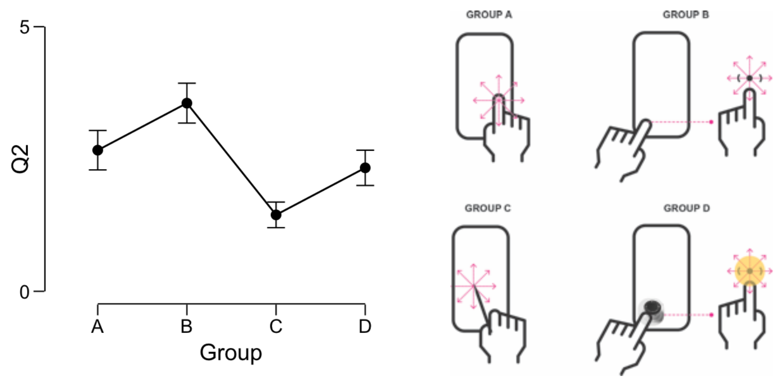
Question 2: *Overall, how easy was it to change movements?*

Q2 was related to finding of satisfactory level for input control in a change of the direction through a long distance. Control movement was to avoid to attack from the enemies through space. Table IV-15 addresses mean values between groups and the satisfactory level was arranged between 1 and 4 value. Both Group C and D were more effective with a satisfactory level of input control and mean value higher than overall mean 2.5 which appeared that Questions 2 were neutral between the easy and difficult level of input control satisfactory. This result reflects that using a finger was not easy to control of movement for a long distance regarding the size of the fingertip.

Table IV-15. Descriptive of Q2

Group	Mean	SD	N
A	2.667	1.118	9
B	3.556	1.130	9
C	1.444	0.726	9
D	2.333	1.000	9

In comparison between groups, Group B was most ineffective for the satisfactory level of changing a long distance movement (Figure IV-14). This finding is the same result as Question 1. The analysis of descriptive value on the graph shows that participants in Group C and D were more satisfied with an input control for long distance movement. This underpins that using a touch pen and joypad was easier to control movement rather than using a finger touch.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-14. Descriptive Plot for Q2

According to the different contrast value in a comparison between each group, Group C appeared effective value compared with Group A and B (Table IV-16). P-Value (p < .002) was bigger than 95 percent in a difference between these groups. This result was significantly different effectiveness when participants were dealing with a long distance movement. This means that users were able to control much easier to grab an airplane into another location in a short period. An accuracy of positioning the airplane to avoid the attack from enemies' fires was much easier and faster by using a touch pen. Regarding the design of the Samsung S-Pen, the tapped point is effective to control a long distance movement as well.

Table IV-16. Difference Contrast – Group for Q2

Comparison	Estimate	Std. Error
B - A	0.333	0.253
C - A, B	-0.500	0.146
D - A, B, C	-0.042	0.103

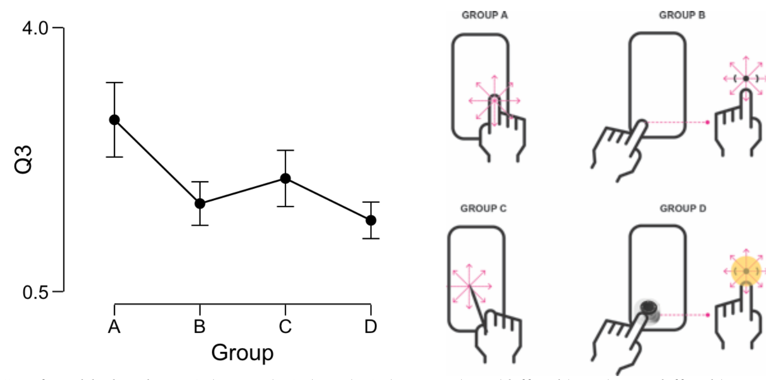
Question 3: *Overall, how easy was it to see contents on the screen while you are controlling interfaces?*

Q3 was related to finding of effectiveness with a direct input control while users were interacting with a touchscreen. Collected responses from participants were measured to seek comfort level between direct and indirect input control of interface design that affects game achievement. Table IV-17 describes mean values between groups A-D. The satisfactory level was arranged between 1 and 3. Group B and D showed more satisfactory value than other groups. This finding underpins that participants were more comfortable with an indirect control, in which participants played the game with a virtual interface and an analog joypad attached on the touchscreen.

Table IV-17. Descriptive - Q3

Group	Mean	SD	N
A	2.778	1.481	9
B	1.667	0.866	9
C	2.000	1.118	9
D	1.444	0.726	9

Through the analysis of the P-Value ($p < .070$), Group A and B appeared as a significant difference with an effectiveness of input control. This result underpins that indirect input control with either finger touch or joypad is more efficient to observe the screen. Users in control by the virtual game interface were able to control much easier to perceive the performance of the game task while they were controlling the airplane movement on the static interface.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-15. Descriptive Plot for Q3

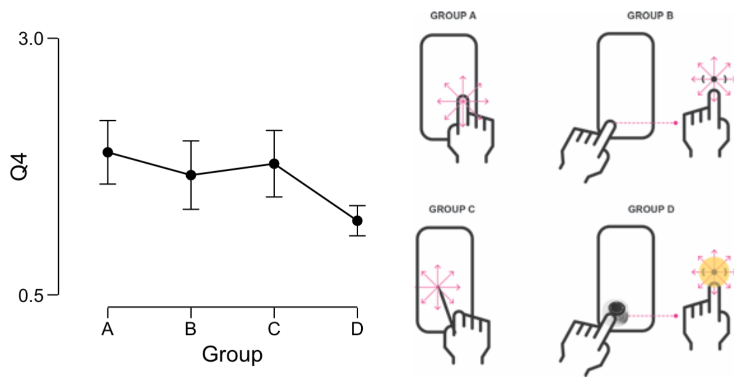
Question 4: *Overall, how comfortable was it to hold a smartphone during a playing a game?*

Q4 was related to finding of effectiveness with a one hand control while users were holding a smartphone device with the other hand. Collected responses from participants were measured to determine accuracy level for the input control of interface design that affects game achievement. Table IV-18 describes mean values between Groups A-D. The satisfactory level was arranged between 1 and 2. This result addresses that participants were comfortable to play the game with one hand.

Table IV-18. Descriptive – Q4

Group	Mean	SD	N
A	1.889	0.928	9
B	1.667	1.000	9
C	1.778	0.972	9
D	1.222	0.441	9

The result shows that participants were similar in responding at the satisfactory level between groups. However, Group D appeared the satisfactory level higher than other groups. According to the result, using a thumb while holding a smartphone is a common activity with using a smartphone for other purposes.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-16. Descriptive Plot for Q4

4.2.5. Findings of Groups E-H

Groups E-H conducted the game "Tank Hero." Each participant conducted the game task by given input control conditions. Table IV-19 shows the mean value of the game score from these groups. The maximum level of the game achievement was 22 and minimum was level 2. The mean value of the total score is 9765 and average of the achievement level was 6.756. The total score was accumulated with Accuracy, Health, and Killing rate through the entire game. However, a higher ranked rate cannot be defined as satisfactory level positively on the efficiency of usability. Instead, the mean value was the average measuring value with each participant's variables.

Table IV-19. Descriptive statistic for game score Group E-H

	Total Score	Level	Accuracy rating	Health rating	Kill rating
Valid	45	45	45	45	45
Missing	0	0	0	0	0
Mean	9765	6.756	914.4	4443	2769
Std. Deviation	1.065e+4	4.647	666.3	3594	4822
Minimum	1327	2.000	135.0	667.0	200.0
Maximum	5.658e+4	22.00	3065	1.600e+4	2.350e+4

Note. Not all values are available for *Nominal Text* variables

Figure IV-17 is an arrangement of value for total score and level from total 45 participants. A majority of participants obtained around 10,000 points which is a similar result with the mean value. The achieved game level was lower than the mean value in terms of the result that a majority of participants achieved the level 4.

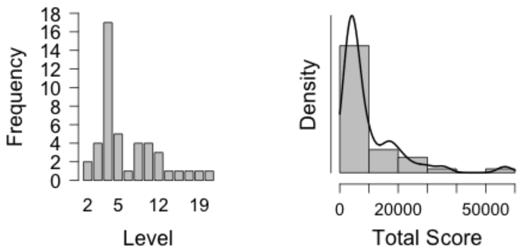


Figure IV-17. Plot arrangement for Level and Total Score

Group E-1 appeared with a significantly different achievement compared with the results from Group E when conducting the same task. With given 15 minutes for pre-exercise provided participants in Group E-1, learning experience to achieve the game level and score were better. According to the study of measurement of input control effectiveness for touchscreen game by Zaman, Natapov and Teather (2010), touchscreen-based virtual controls was effective once users adopted the "familiarity of perception" with game interface and rules. Participants performed the game control better for less number of death and longer completion time of game play once they played the game with more numbers of a trial. Group E-1 appeared with the same result as participants became familiar with touchscreen input control on learning experience in a short period.

Analysis of Level

Figure IV-18 describes average achieved level of each group in a comparison. According to the same condition of given task between Group E and E-1, there was significantly different game achievement between these two groups. Group E-1 achieved level much higher than group E. This result underpins that touchscreen on two hands was more effective once a user becomes familiar with a game control through 15 minutes pre-exercises during the usability test.

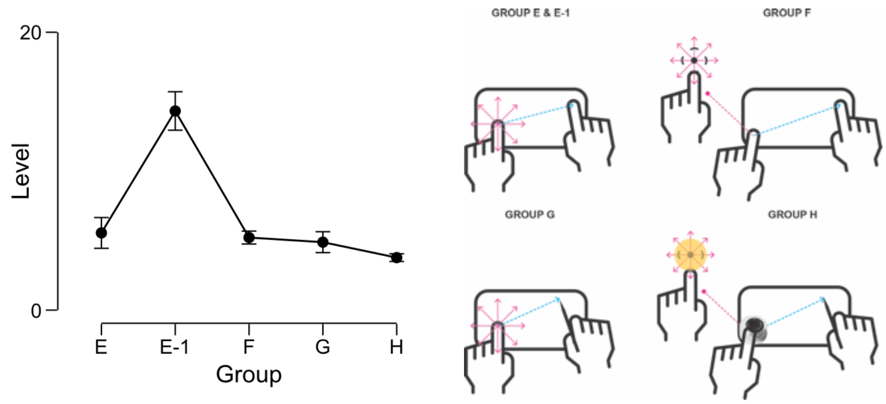


Figure IV-18. Plot arrangement for Level per each group

Overall male users achieved level better than female users, but there was not a significant difference between gender. However, P-Value was lower than 0.05 ($p < .001$) which was significantly different effects from each group (Table IV-20). Additional measurements of mean values comparing each group was necessary through the survey questionnaires.

Table IV-19. Correlation with group and gender for Level

Cases	Sum of Squares	Mean Square
Group	458.16	114.540
Gender	17.11	17.112
Group ✻ Gender	17.06	4.266
Residual	249.99	7.142

According to the analysis of correlation with the group, there appeared that the result of game achievement level from each group was affected by different input control conditions. This result is drastically different from one hand input control in which only a joypad was a significant effect from other input control conditions. P-values of correlation with the group on Figure IV-21 shows that using a physical controller on the touch screen was less effective in a result of the game level achievement.

Table IV-21. Correlation with group for Level

Comparison	Estimate	Std. Error
E-1 - E	4.321	0.698
F - E, E-1	-1.405	0.426
G - E, E-1, F	-0.929	0.268
H - E, E-1, F, G	-0.776	0.236

Participants in Group E-1 achieved the game level significantly higher than other groups. Once they took pre-exercise of playing the game, all participants performed the game effectively even though there were only 15 minutes allowed for play. Group H was the most ineffective on the achievement of a level. This describes that using an analog input controller in both hands were difficult or uncomfortable to perform the game. According to the similar appearance of the Standard Deviation (SD) through each group, this data is reliable to verify the variables as being stable between each group (Table IV-22).

Table IV-22. Descriptive of Level

Group	Mean	SD	N
E	5.556	3.321	9
E-1	14.333	4.153	9
F	5.222	1.394	9
G	4.889	2.261	9
H	3.778	0.833	9

Analysis of Score

The measurement of the total game score from each group appeared as a similar value with the achievement level. Figure IV-19 shows the same variable result as using a physical input controller on the touchscreen were less effective on the game score. According to the variables on participants, the value of the total score was slightly reduced except Group E-1.

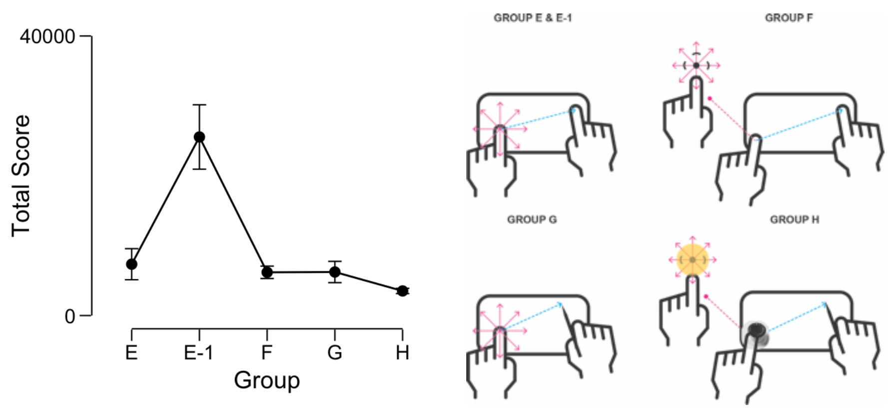


Figure IV-19. Plot arrangement for total score per each group

Table IV-23 contains a detailed analysis of the overall mean of the total score in a comparison between each group. However, Standard Deviation (SD) indicates a much variable difference between each group and participants in Group F and H were stable for the effective mean value. Thus, this values cannot be efficient for the measurement of the effectiveness with satisfactory level.

Table IV-23. Descriptive of total score

Group	Mean	SD	N
E	7346	6675	9
E-1	25548	13826	9
F	6184	2666	9
G	6229	4574	9
H	3518	1130	9

According to the P-Value on Table IV-24, the total score was significantly different effects from each group. Especially, P-Value ($p < .001$) from between Group E and E-1 was the most significant effect in comparison with a total score. This result was the same as an effectiveness of the achievement level between these two groups. It is necessary to see if there is also a significant difference if Group E-1 still shows a high rate in satisfactory level on survey questionnaires.

Table IV-24. Difference Contrast of total score

Comparison	Estimate	Std. Error
E-1 - E	8999	1950.1
F - E, E-1	-3169	1190.3
G - E, E-1, F	-1813	747.8
H - E, E-1, F, G	-1644	658.8

Analysis of Accuracy Rating

Accuracy rating was collected by the game score. Accuracy rate was measured by a configuration of the successful shooting to the target per each fire. If any shooting was missed, the accuracy score was decreased. The score numeric is not related to the game achievement. As Figure IV-20 shows an arrangement of the mean value in comparison with each group, Group E-1 appeared much higher rate on the accuracy. This result was considered that participants became familiar with perception and awareness of measuring the target on the screen. However, the Accuracy Rating in Group G and H appeared lower than other groups, and this means that using the S-pen to shoot at the target was not effective compared with input control by a finger touch.

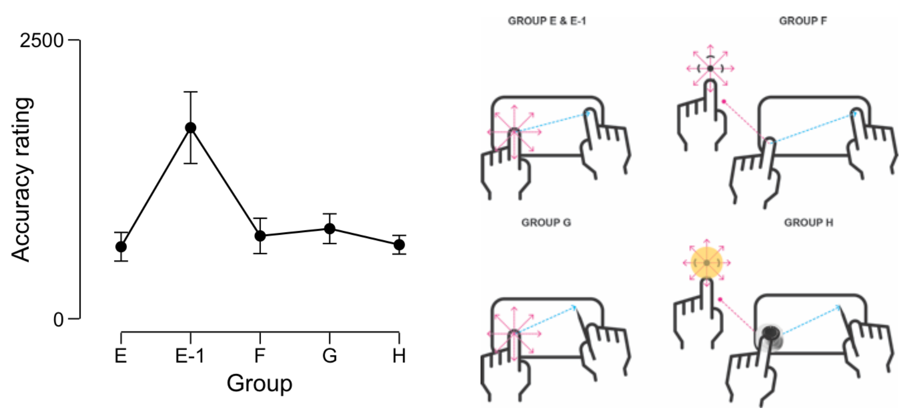


Figure IV-20. Plot arrangement for accuracy rating per each group

Table IV-25 is ranged by the accuracy rate based on the mean and standard deviation value per each group. Except for Group E-1, there were not a significant difference between each group. However, the mean value of male participants in Group F was higher than the entire mean value

(1224 > 914). This rate is also the second ranked in the accuracy rate among the male. This result supports male participants were comfortable to control fingers for both shooting and movement while female users were similar with the consequence from other groups.

Table IV-25. Descriptive for accuracy rating

Group	Mean	SD	N
E	645.4	385.8	9
E-1	1713.0	963.7	9
F	742.7	475.0	9
G	807.6	399.9	9
H	663.6	250.8	9

Analysis of Survey Questionnaires

With the completion of the usability test, each participant answered the survey questionnaires. There are a total of six questions that address their experience of a task with the given input control condition. The value of satisfactory level from each question is related to the result of other findings such as total score and game level achievement. Questions were comprised of usability of game controller between finger touchscreen and an analog game control on the touchscreen. The questions are:

Q1: Overall, how easy was it to change directions?

Q2: Overall, how easy was it to change movements?

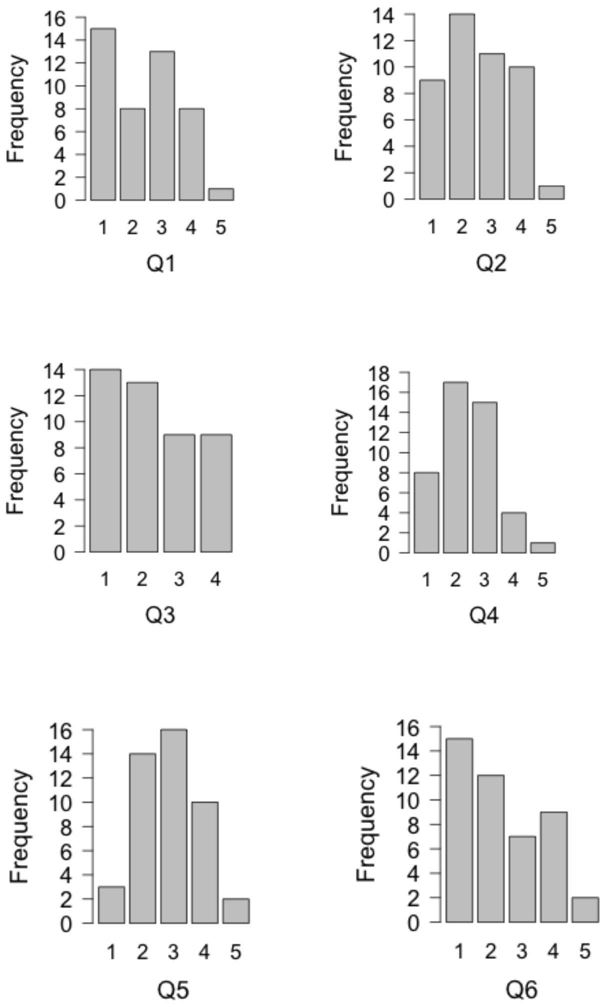
Q3: Overall, how easy was it to see contents on the screen while you are controlling interfaces?

Q4: Overall, how easy was it to aim for the target in shooting?

Q5. Overall, how easy was it to control both movement and shooting at the same time?

Q6. Overall, how comfortable was it to hold a smartphone while playing a game?

The answers were arranged with 1 as "easiest" and 5 as "most difficult." Figure IV-21 shows the number of answers from the entire groups. Satisfactory level showed various responses per each question. Unlikely Group A-D in the measurement of one hand input control satisfactory, Group E-H responded to each question differently between easy and difficult rate. The mean value was between 2 and 3. In regards to this result, it is necessary to find a detailed analysis of the difference between each group and question.

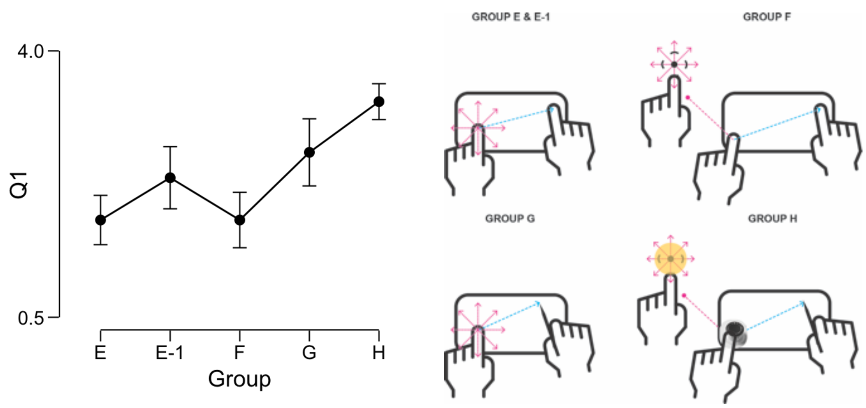


** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-21. Result of Survey Questionnaires

Question 1: *Overall, how easy was it to change directions?*

Q1 was related to finding of satisfactory level for input control in a change of the direction. The tank was controlled to rotate 360 degrees to change the direction. Figure IV-22 addresses mean values between groups. There was a big contrast between Group E and H overall. Participants were ranked between 1and 2 in Group E, 3 and 4 in Group H. This measurement of the survey result underpins that participants were more comfortable with input control task on finger touch rather than a physical control on the touchscreen.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-22. Descriptive Plot for Q1

Question 2: *Overall, how easy was it to change movements?*

Q2 was related to finding of satisfactory level for input control to move the tank in both short and long distance. The methods for input control of this movement were arranged with dragging a finger (Group E, E-1 and G), tapping or press-holding a virtual joypad by finger touch (Group F) and a physical joypad on the top of a touch screen (Group H). While a user controls movement, the number of graphic arrow guidelines indicates a distance on the screen (Figure IV-23).

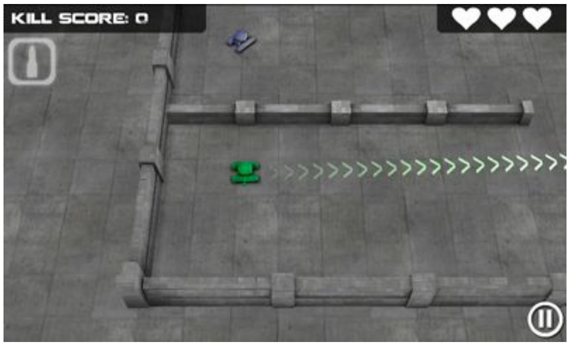
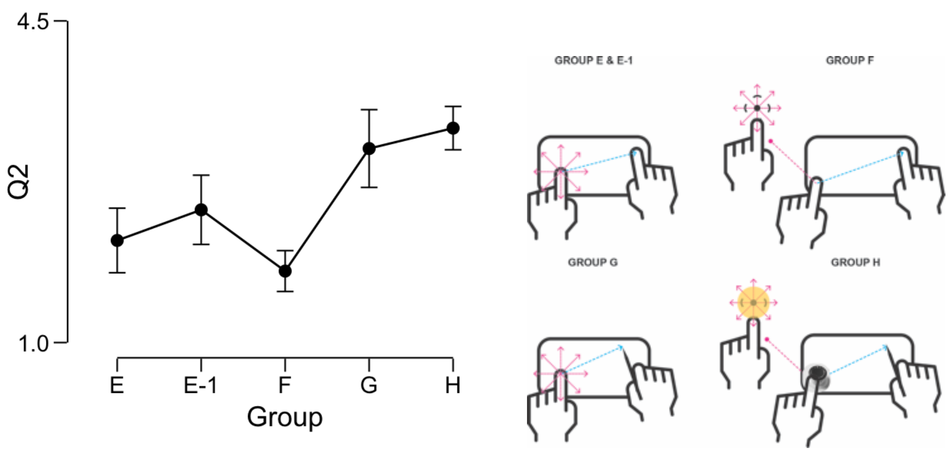


Figure IV-23. Input control for tank movement

The result from the survey answers appeared similarly to Q1. Participants in both Group G and H were less satisfied with physical controllers for movement (Figure IV-24). This underpins that multi-tasks by two hands control mixed with digital and analog interaction were not effective. However, Group E-1 was slightly less satisfied with a finger touch compared with Group E. This result was based on the difficulty of the game level while participants were dealing with speed and heavy traffic on the screen.



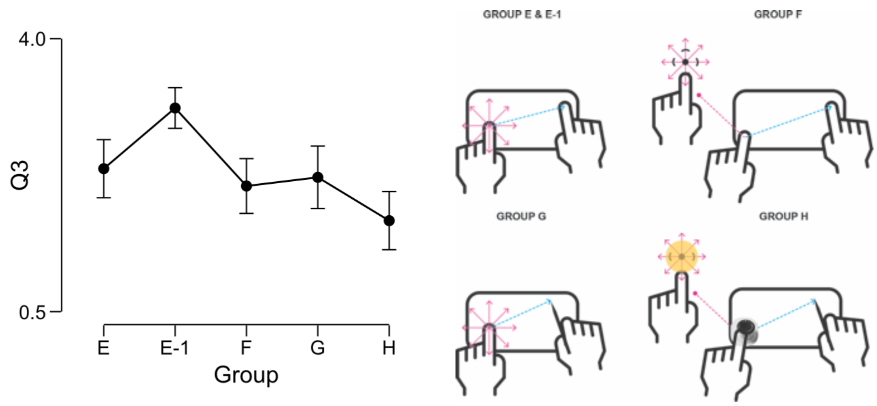
** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-24. Descriptive Plot for Q2

Question 3: *Overall, how easy was it to see contents on the screen while you are controlling interfaces?*

Q3 was related to finding of effectiveness with given input control condition. Figure IV-25 shows different comfortable level with each group. Regardless of the game achievement result that

Group H was the lowest, participants in Group H responded the most satisfaction with seeing contents on the screen while a user was controlling interfaces. This result shows that using a physical controller was easier to play the game within limited small touch screen. This means that direct input control on the screen was not effective. Two control tasks with fingers on the touchscreen was especially ineffective when the game was on heavy attacks.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

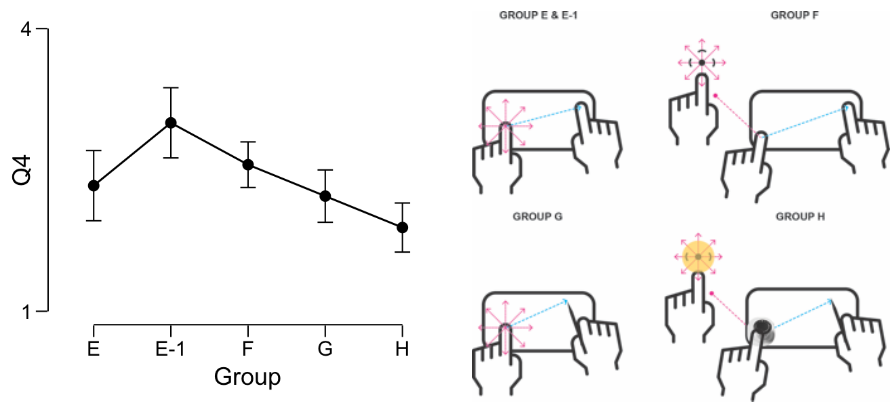
Figure IV-25. Descriptive Plot for Q3

According to the P-Value in a comparison between groups, only Group H appeared less than 0.05 which value is a significantly different effect. As participants in this group were most comfortable to see the screen, indirect input control for both movement and shooting allows users to interact with game performance more efficiently.

Question 4: *Overall, how easy was it to aim for the target in shooting?*

Q4 was related to finding of accuracy level with given input control condition. The shooting action task was based on touching the screen directly with either a fingertip or a touch pen. Figure IV-26 shows different values of each group. According to the mean value between each group, Group H appeared the most satisfactory compared with other groups. The mean value of 1.889 shows the fact that participants felt aiming for the target in shooting with a touch-pen (S-pen) easiest. However, Group E, E-1 and F was not satisfied with aiming for the target in the shooting.

This result shows that finger touch is not efficient to move the control faster and it is more difficult to see content on the screen. In contrast with this result, using a physical controller on the screen was more effective for aiming at the target while the other input control was interacted by a finger touch.

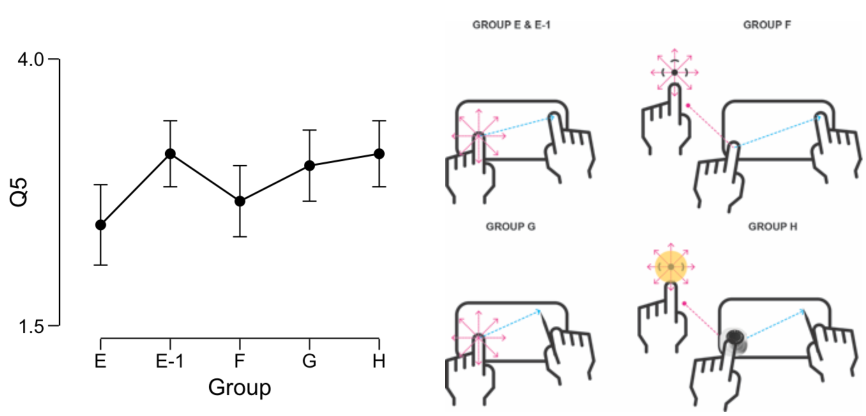


** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-26. Descriptive Plot for Q4

Question 5: *Overall, how easy was it to control both movement and shooting at the same time?*

Q5 was related to finding a satisfactory level with given input control condition. Figure IV-27 shows different values between each group. This question found that both movement and shooting action task simultaneously was more effective in Group E and F. This result underpins that users were more comfortable to operate input control task with directed touchscreen rather than mixed or using only a physical controller.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-27. Descriptive Plot for Q5

However, there was unexpected findings in Group G. All five female participants were playing a game with one hand input control with a touch pen. This happened in the middle of the game performance. While all these participants were controlling input control tasks for both shooting and movement with two hands at the beginning of the game, they found that using a touch pen was much more effective on multi-tasks. Participants answered the open-ended question that they felt more comfortable for playing the game much faster and easier to control even though the game score and achievement level was not much effective (Figure IV-28).

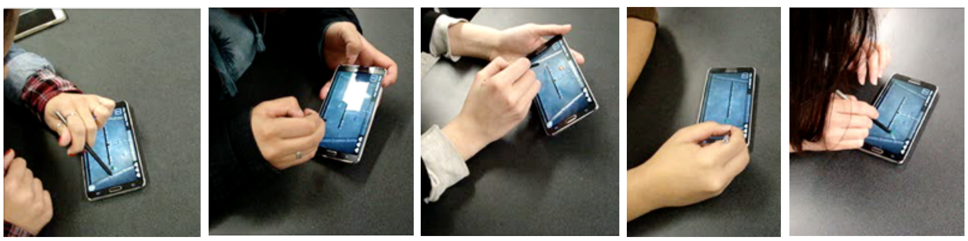
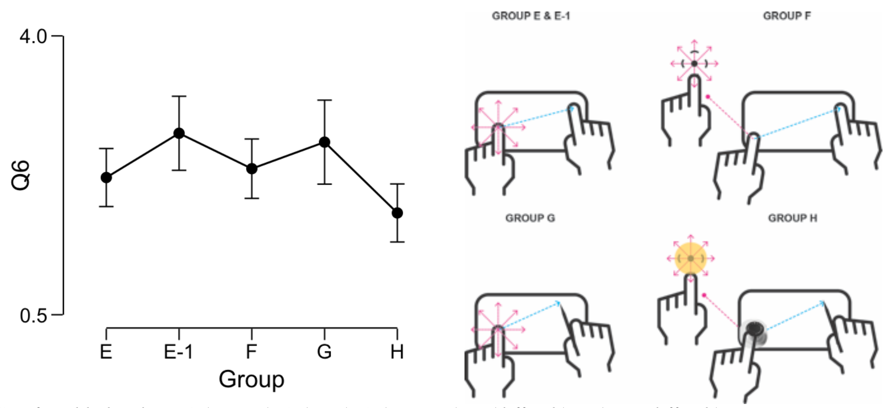


Figure IV-28. Female participants in Group G

Question 6: *Overall, how comfortable was it to hold a smartphone while playing a game?*

Q6 was related to finding a satisfactory level with given input control condition. Figure IV-29 shows different values of satisfactory level between each group. While participants were getting satisfied with using a physical controller, participants' variables were not consistent between finger touch and physical control. Group H showed that it was most comfortable to hold a smartphone while participants were playing a game with both hands. Group H appeared only a different effect in P-Value ($p < 0.036$) between other groups, but P-Value 0.052 in between Group E and E-1 was almost close to 95%. This result underpins that E-1 group felt more discomfort as they achieved the game level better. According to the difficulty of the game level, the enemies' attack was heavier and much fast in movement.

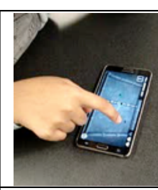


* *Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-29. Descriptive Plot for Q6

However, some participants in both Group E and E-1 showed the unexpected finger gesture. According to these two groups in the same control task, different interactive figure action was observed by a few participants. Table IV-26 is screenshots that appeared during a task from these two groups. Some users played the game with one hand to control both shooting and movement at the same time. Some users played the game without holding a smartphone by one or two hands input control. Participants in Group E-1 met the game achievement better than Group E while they were using index finger(s). All those involved in Group E and E-1 used index finger(s) instead of thumb(s) for input control of shooting and movement. This action has reflected the result of accuracy rating and comfortable level.

Table IV-26. Finger gesture with two hands in Group E and E-1

Finger gesture						
Group	Group E1	Group E3	Group E8	Group E-1-1	Group E-1-2	Group E-1-3
Level	5	6	10	19	10	12
Score	4133	7141	15972	35470	16913	20988
Accuracy rating	464	672	970	2835	912	1025
Q6 Rate	3	4	3	5	4	3

* *note: Mean value (Level=6.756; Score=9765; Accuracy rating=914.4; Q6=2.356)*

4.3. Summaries of Usability Test

Through the measurement, evaluation of the survey and the open-ended questions, this study shows different effectiveness between digital and analog input control tasks. According to the evaluation of the result from the usability test, this study found that direct touch screen interaction is more effective on two hands input control task. Using an indirect physical input control was more effective on one hand touchscreen.

4.3.1. Comfort Level

The comfortable level was measured and evaluated by the survey questions. For one hand input control, questions 4 compared with total score and time was assessed. The result appeared that Group C and D were the most effective on the comfort level (Figure IV-30). Participants in these two groups played the game with an analog controller while they were holding a smartphone by the other hand. Participants felt more stable to concentrate on the game task.

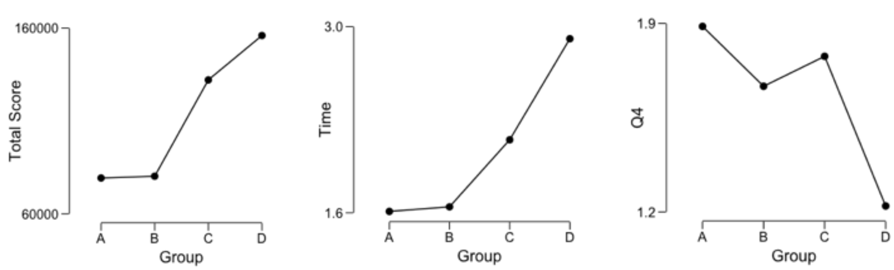


Figure IV-30. Comfort level on one hand input control

For two hands input control, questions 3 and 6 compared with total score and game achievement level were evaluated. The result appeared that Group E and F were the most effective on the comfort level (Figure IV-31). Participants in both these groups played the game with finger touch better in terms of easiness of seeing the entire screen. Most users used their thumb on the left hand to control movement as a primary input control task while the other hand controlled to shooting at the target with an index finger.

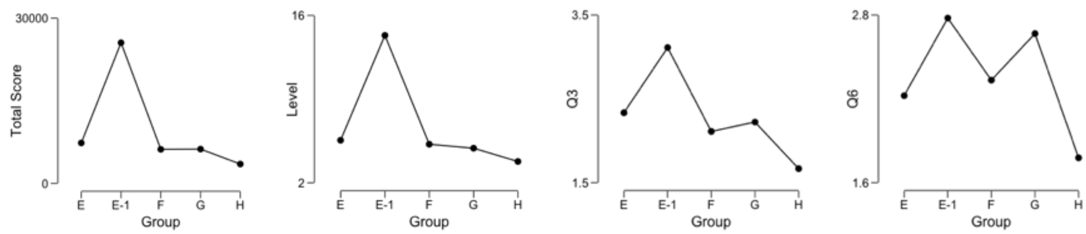


Figure IV-31. Descriptive Plot for the comfort level on two hands input control

4.3.2. Effectiveness Level:

Effectiveness level was measured by values as how effectively participants conducted the input control task for multi-tasking of both shooting and movement. For one hand input control, game achievement value in total score and time was evaluated for an effective variable with question 3. The result appeared that Group D was the most effective on the game achievement for both total score and time length (Figure IV-32).

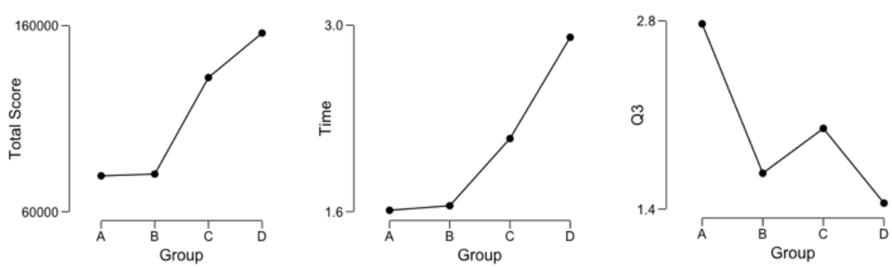


Figure IV-32. Effectiveness level on one hand input control

For two hands input control, questions 1 and 5 compared with total score and game achievement level were evaluated. The result appeared that Group E and F were the most effective on the comfort level (Figure IV-33). Participants in both these groups played the game with finger touch for both shooting and movement that allows users to be more stable to concentrate on the game task. These two groups also appeared effectiveness level of changing direction better than other groups regarding prompt responses of the input control with a fingertip.

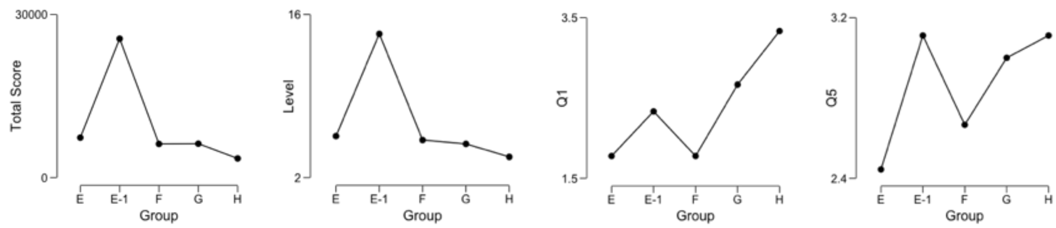


Figure IV-33. Effectiveness level on two hands input control

4.3.3. Accuracy Level:

Accuracy level was measured by values as how effectively participants were able to conduct the input control task. For one hand input control, game achievement value in total score and time was evaluated for an effective variable with question 1 and 2. The result appeared that Group D was the most effective on the game achievement for both total score and time length (Figure IV-34). Participants in both Group C and D appeared that they were satisfied with a control input task for movement (question 3 and 4). The game score of Group C was higher than the mean score compared with Group A and B. This result evidently recommends that using an analog controller with one hand control is much more accurate for the control movement.

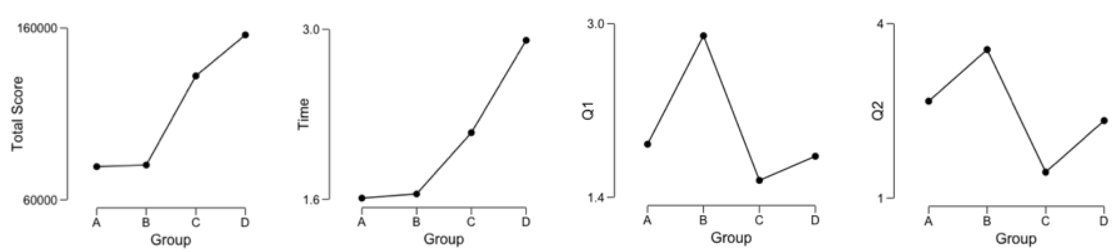


Figure IV-34. Accuracy level on one hand input control

For two hands input control, questions 2 and 4 compared with total score and accuracy rating were measured for findings. Game score and accuracy rating appeared as an outstanding value in Group E-1 (Figure IV-35). This result occurred because participants became familiar with methods and strategy of input control through pre-exercise for 15 minutes. However, satisfactory values in question 2 and 4 were less satisfactory compared with other groups. This result causes that Group E-1 faced with heavier attacks and fast movement from many enemies on a difficulty of the game level. Regardless of measurement of the accuracy level, Group E-1 was excluded regarding different condition for the usability test. Overall, Group E and F appeared more effective values for the accuracy level, and this demonstrates that two hands input control was more accurate with direct fingertip interaction on the touchscreen.

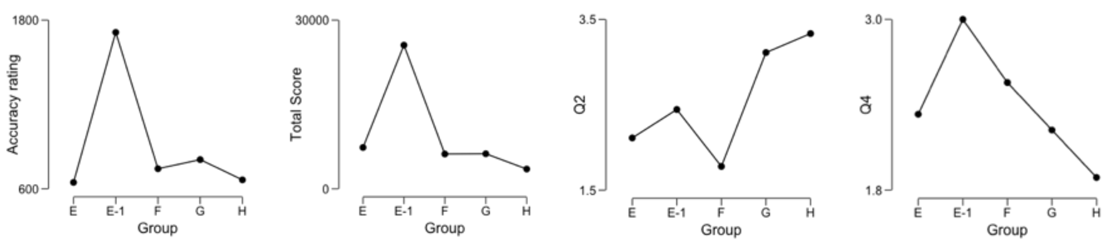


Figure IV-35. Accuracy level on two hands input control

4.3.4. Summary of User Behaviors and Open-ended Discussion

User behaviors and finger gestures were observed during their performance of the usability test. There were common findings among participants, but distinctive behaviors and finger gestures were analyzed to discover how it affects or influences game achievement and satisfactory level. Analysis of user experience with interactive input control tasks as following summaries:

- Participants in Group A were holding a smartphone device with one hand and controlled the movement and bomb shooting with the other hand. All users in these groups used an index finger regardless of being left or right-hand user. However, Group E and E-1 showed three different behaviors (Figure IV-36); some participants were using their thumbs on both hands to control movement and shooting while a few participants were using both thumb and index finger. According to Figure IV-31, three participants played with both index fingers to change the input control between movement and shooting to control the input task for a faster reaction during a game. Regarding unrestricted control method on the touchscreen control interface, participants found their comfortable manners to interact with movement and shooting.

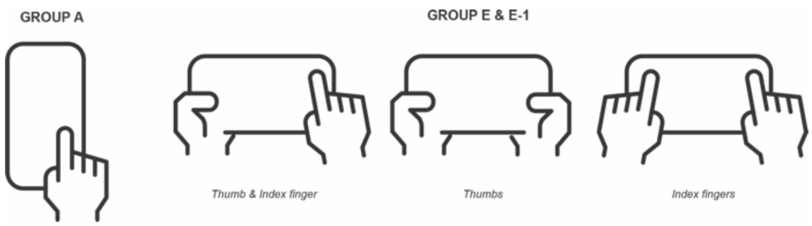


Figure IV-36. Finger gestures and control behavior between Group A, E and E-1

- Figure IV-37 showed the rest of groups in which participants controlled the graphic input interface and analog input control in the same way. According to static movement control interface in Group B and D, all participants were using their left-hand thumb regardless of prefer handedness. Participants in Group G and H appeared the most discomfort to control both movement and shooting. During the open-ended discussion, they responded that perception of two different input control action was not easy in terms of holding a smartphone and control both analog controller on the touchscreen. This behavior and experience appeared negatively distracting the game comfort and achievement through the analysis of statistic values as well.

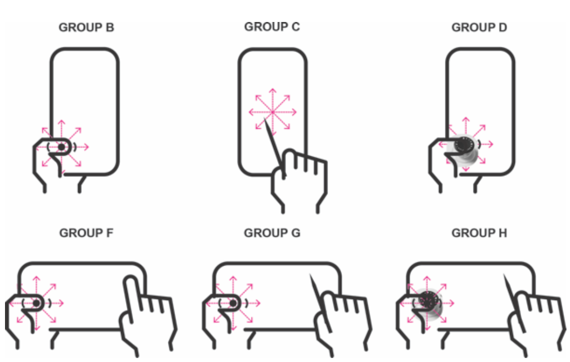
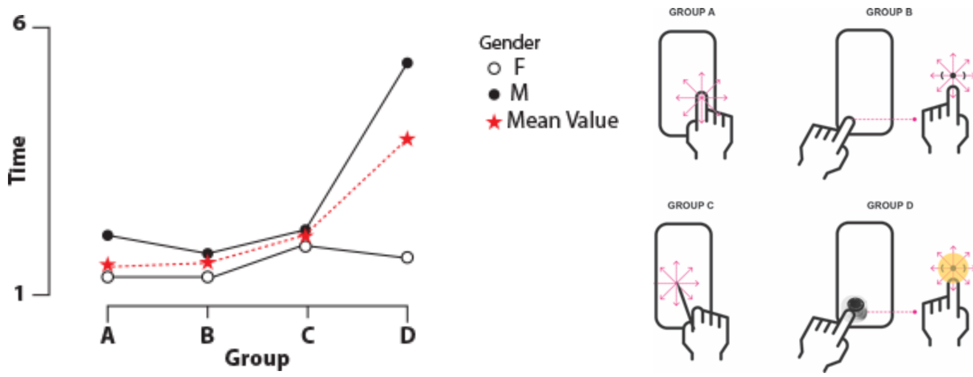


Figure IV-37. Input control with graphic interface and analog controller

A question in the open-ended survey, most participants wanted to see a physical controller in future smartphones. Users consider either home button or some buttons on a smartphone would be more effective not only for playing smartphone games but also using other apps. Most participants in Group C, D and H also consider that either built-in or attachable joypads would be user-friendly to control the game difficulty and accuracy of multi-task on smartphone games. According to all participants experienced with video/PC or console games, they were not comfortable to conduct multiple input control tasks on a touchscreen in terms of limited space with heavy traffic of fingers' movement. Overall participants in Group A-D with one hand control were more satisfied than Group E-H with two hands control.

4.3.5. Discussion with Different Effectiveness based on Gender

This study found an unexpected result based on gender. Among the group, a value of the result appeared significantly different effect between male and female. The following addresses these findings and discussion for a future study. Figure IV-38 describes the average time length of each group in a comparison between male and female. Males played longer than females, and Group D shows a significantly difference between male and female. Regarding the given input control condition, touch with a joypad on the virtual interface was easier for male participants. This graph also interprets that Group C as playing the game with a touch-pen was the most efficient result for playing a game for a longer time. Female users in Group C played longer than other groups. This finding explains that male users are more familiar with an analog control than female users regarding their prior experience with video and console games.



Note: Time (minute)

Figure IV-38. Plot arrangement for analysis of playing time in Groups A-D

Figure IV-39 shows the comparison of total score between male and female. With a similar result from the time-length, Group D also appears to have a significant different value between male and female. This underpins that female participants in Group D were less effective with using a physical joypad control on the touchscreen.

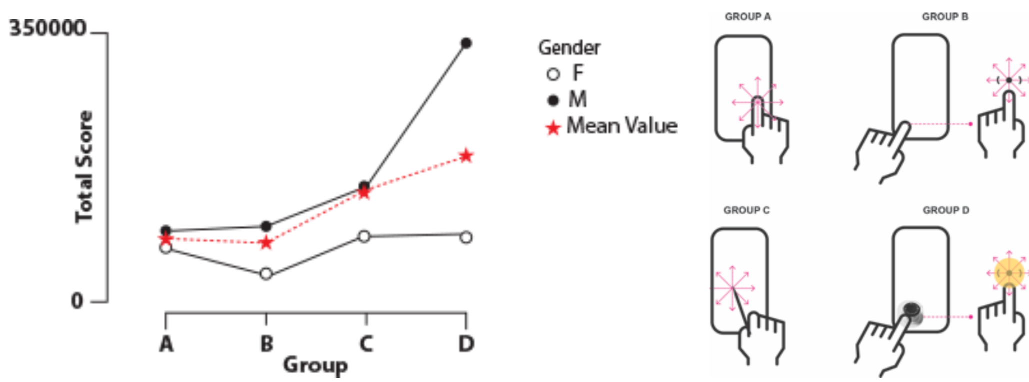
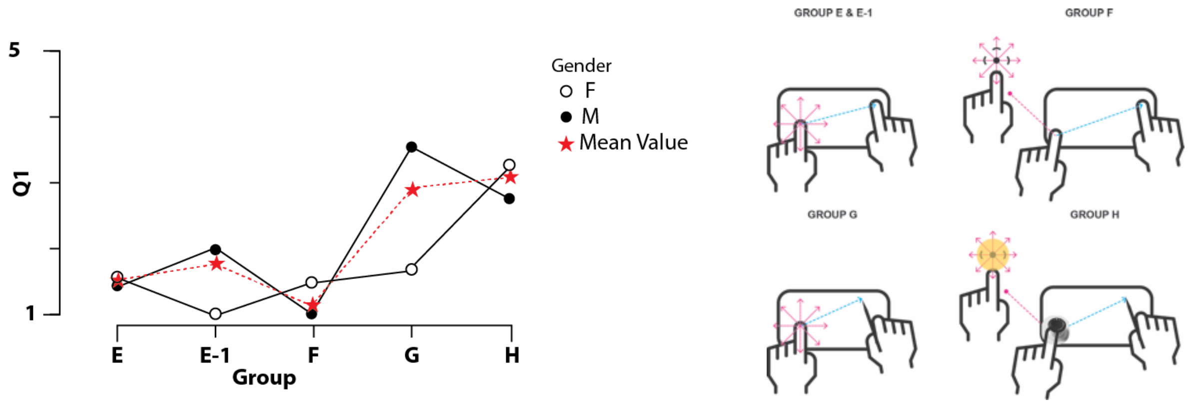


Figure IV-39. Plot arrangement for analysis of total game score in Groups A-D

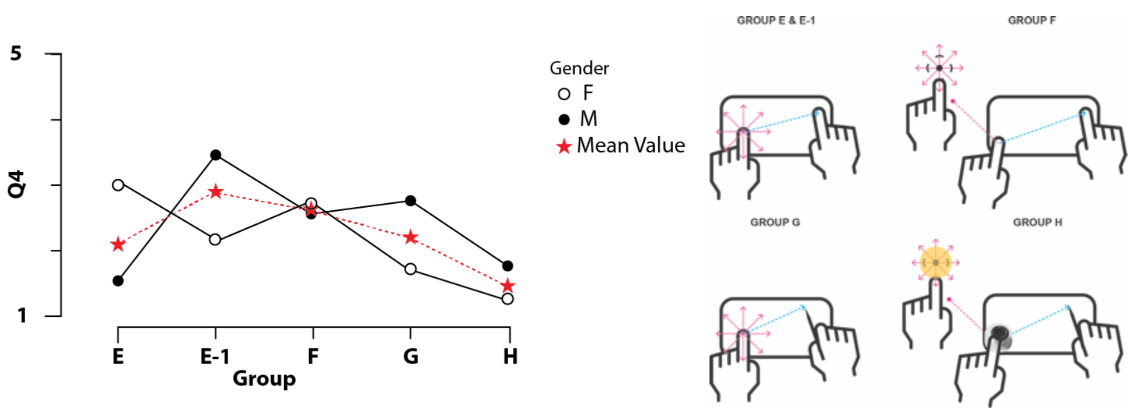
Figure IV-40 addresses mean values between group and gender on Question 1 from Groups E-H. The satisfactory between male and female appeared differently. There was a big contrast between Group E and H overall. Both male and female participants were ranked between 1and 2 in Group E, 3 and 4 in Group H. This measurement of survey result underpins that participants were more comfortable to control input control task on finger touch rather than a physical control on the touchscreen. Among the male participants, Group F was the most satisfied with the change of direction. Female users were more comfortable with input control after pre-exercise for 15 minutes. There were also significant different satisfactory values between male and female in Group E-1 and G. In these two groups; male participants responded that they had more difficulty with the direct touchscreen while they were using a physical control on the other hand.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-40. Descriptive Plot for Q1 in Groups E-H

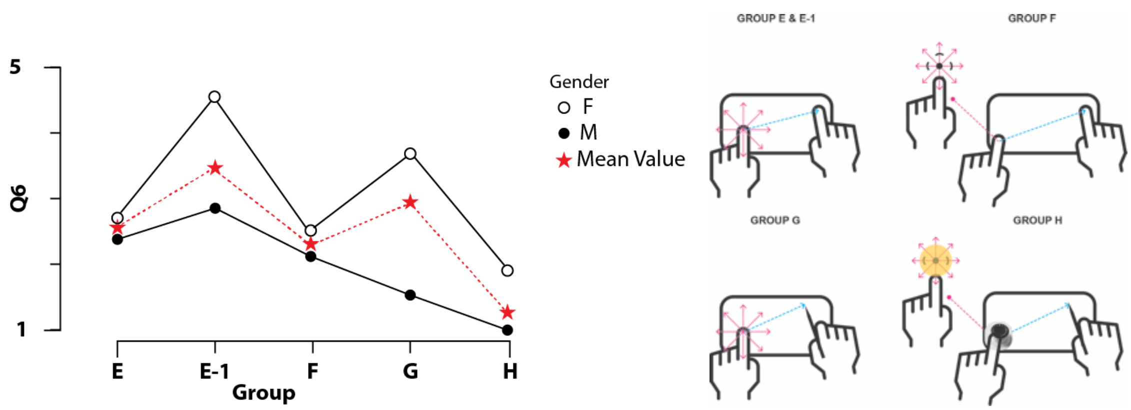
Figure IV-41 addresses different values of each group between male and female participants. Male and female in group E showed much different satisfactory level. Overall, female participants were more satisfied with a physical controller for shooting at the target. This result appeared to be similar with accuracy rating value.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-41. Descriptive Plot for Q4 in Groups E-H

Figure IV-42 shows different values of satisfactory level for male and female between each group. While male participants were getting satisfied with using a physical controller, female participants' variables were not consistent between finger touch and physical control. Group E-1 showed the most discomfort, and there was a big satisfactory difference between male and female. As both participants achieved the higher game level, female participants were unsatisfied with holding a smartphone while playing a game. Group G also showed male participants were more satisfied with using a physical control than female users. Thus, male users appear to be more effective with input control tasks while they were holding and controlling movement and shooting with both hands.



** Comfortable level: V=1 (easiest), 2 (easy), 3 (average), 4 (difficult), 5 (most difficult)*

Figure IV-42. Descriptive Plot for Q6 in Groups E-H

V. CONCLUSION, DISCUSSION AND FUTURE STUDY

The objectives of this study were to find empirical evidence for the effectiveness of user interface and interaction between digital and analog input control system. The usability test of the main study was primary to compare user's behaviors, responding of accuracy, swiftness and effectiveness, and perceptive cognition with a touchscreen-based and physical input control.

According to the hypothesis (*If smartphone users were experienced with a digital touchscreen interface, they would have a positive experience through playing a smartphone game on a touchscreen as well)* and research questions *(digital interface is more effective for all operating system than an analog interface? Is there any empirical evidence comparing digital and analog interface on a smartphone since various types of the smartphone game controller have been introduced in the gaming market?),* the study developed the usability test to discover a quality of user interaction with a game input control in a comparison between touchscreen-based and analog control. Evaluation for finding the game achievement, effectiveness, ease of use, accuracy and comfort satisfaction of game input control was analyzed by measurement of collected values between two conditions through the gameplay.

5.1. Conclusion

The result from the Pilot study demonstrated that touchscreen was more effective with playing a game as directed input control task than multi-input control tasks with a game controller. However, participants were not absolutely positive with smartphone game required by multi-task input control. Instead, all participants were positive with games considered by a touchscreen-based interface which appeared suitable interaction for dynamic input controls of a single task.

Smartphone touchscreen was easier to tap and move an object and faster responding. However, a lack of tactile responding and blocking screen view while participants were interacting with input control on the touchscreen were not effective for game satisfactory and conformable level. Even though touchscreen-based input control appeared more effective on given tasks, other evidence was not absolutely positive with touchscreen only. Moreover, control movement and action tasks in comparison to the dependent values showed an equal quality of the game control usability. Thus, using a gaming controller would not be adequate if a smartphone game was not designed with consideration of the interactive platform for the touchscreen input control interface. These conflicts result between games and input control was considered to develop the main study to find the effective game style and input control interface design.

According to the result of the Pilot Study that multi-input control on smartphone games are not effective for game achievement, the main study focused on the effective relationship between game input control and control methods. The primary objectives of the main study were to discover the effectiveness of input control interaction for smartphone gaming environment; touchscreen-based input control vs. analog built-in input control and one hand vs. two hands game control interface. In contrast with the result in the Pilot Study, the main study found that using an analog input control on the touchscreen for one hand control game was the most effective on the achievement of time and score. Both touch-pen and joypad appeared comfortable level much better than finger touch basis. However, two hand control tasks showed the opposite with one hand control result. Participants on finger touch input control achieved the game level and score better than analog control basis, but it was not much different with accuracy rating. By providing 15 minutes' pre-exercise for Group E-1, the result compared with other groups appeared significantly difference through entire game achievements. This result was related to the *"familiarity of* *performance,"* that participants performed the game control better for less number of death and longer completion time of game play once they played the game with more numbers of a trial, but it does not affect the evaluation of usability.

Other findings through observations, two hands control game on touchscreen appeared three different type of figure gestures and orientations 1) thumb & index finger control, 2) thumbs control, and 3) index fingers control. However, one hand finger-touch -based input control was consistent with using either left or right index finger. Even though finger-touch input control was more effective than analog input control on the touchscreen, most participants positively responded with the built-in physical control from their performances and experiences. Thus, users prefer finger-touch-input control more flexible to create their interactive control method either one or two hands smartphone games. These findings would be significant guidelines and recommendations to game designers and developers.

In conclusion, the empirical result from the usability test answered research questions that were raised in the main study. First, this study recommends that built-in analog controller is more effective with one hand touchscreen-based input control for the single task of "change of direction and movement" only. This finding underpins using a touch pen and joypad is comfortable with the control input interface that allows users to reach the game achievement efficiently. Second, the empirical usability study argues that finger touch-based input control by two hands is more effective for dynamic interaction with multi-task such as both movement and shooting in arcade games. This result addresses that direct input control on the touchscreen appears satisfaction of gameplay better than using a built-in controller. However, the game achievement based on the game score and level is not significantly different between touchscreen and a built-in controller. Third, analysis of accuracy level shows that finger touch-based input control is more accurate once users become familiar with finger gesture-based input control. However, one hand finger gesture-based input control was not effective compared with a built-in controller. Thus, the hypothesis of this study is not true that experienced smartphone users are absolutely positive for smartphone games on a touchscreen. With all these findings in a usability test, this study argues that smartphone game developers and designers should consider a game input control environment with smartphone device rather than a game design based on touchscreen-basis only.

5.2. Discussion and Future Study

Empirical findings from this study suggest that smartphone game needs to consider game design for touchscreen environment-friendly, but both finger-touch-basis and analog touch-based input control need to be considered. If input control requires multi-tasks such as movement and shooting, game control would be more effective with unrestricted touch interaction by finger gestures. A single input control would be user-friendly if the game is designed based on the built-in controller. As the consideration for the types of the smartphone game, one hand control with an analog control would be more effective for the game which requires a control of direction/movement of speed, accuracy and completion time. Two hands input control with finger gestures directly interacted with a touchscreen would be more effective for the type of strategy games which requires users to oversee multi-tasks input control such as simultaneous control with shooting, and change of direction and movement. According to the unexpected findings of the satisfactory level in a comparison between male and female from Group E and E-1, this study found that participants were getting frustrated with input control action by finger gestures on the touchscreen when they achieved advanced game level. This underpins that the input control interface and interactive action by finger gestures from two hands control task on a touchscreen are less effective when the game control requires speed and accuracy. With this result, this study can expand usability tests for finding the efficiency of level between male and female based on the game level and achievement. Moreover, different satisfactory level from game player's performance based on the game level will be an important consideration for the evaluation of the effectiveness with usability in smartphone game design. It may affect the determination of nature for smartphone game and its limitation to be equivalent with PC or Video Game. In terms of the current touchscreen-based smartphone game, relevant researches showed the fact that transition of arcade video or PC games into smartphone games is limited to interact with game input control as same effectiveness. For the future study, this research is predicted that smartphone game industry will introduce the new game design interface with gestural-based interaction on various type of the touchscreen games. Even though moveable two hands-gestural touchless input control have provided dynamic game experiences, the nature of the input control is limited to the game design and contents. Thus, it is significantly impact to conduct usability test for various input control tasks to discover efficiency of the smartphone game environment. Continuing implications of finding different effectiveness of game control interface will affect not only user experience in game design, but also user interface in product design.

REFERENCES

Aarsand, P. A., (2007). Computer and video games in family life: The digital divide as a resource in intergenerational interactions. *Childhood, 14*(2), 235-256.

Albrechtsen,H., Andersen, H. H. K., Bodker, S., & Pejtersen, A. M. (2001). *Affordances in activity theory and cognitive systems engineering.* Riso National Laboratory. Riso-R-1287(EN), 1-38.

Andersen, C. U., Pold, S., & ebrary, I. (2011). Interface criticism: Aesthetics beyond the buttons Aarhus University Press.

Baudisch, P., & Chu, G. (2009). Back-of-device interaction allows creating very small touch devices. Paper presented at the 1923-1932. doi:10.1145/1518701.1518995

Beck J. & Wade M. (2006) *The Kids are Alright: How the Gamer Generation is Changing the Workplace*. Harvard Business School Press, Boston, MA.

Behrmann M, Noyons M, Johnstone B, MacQueen D, Robertson E, Palm T and Point J (2012). "State of the Art of the European Mobile Games Industry" (PDF). Mobile GameArch Project. Retrieved 2015-10-12.

Beniger,JamesR. (1986). TheControlRevolution:7~chnologicalandEconomic Originsofthelnj~rmationSociety.Cambridge, MA:HarvardUniversityPress.

Bevan, N. (1995). Measuring usability as quality of use. *Software Quality Journal, 4*(2), 115-130. doi:10.1007/BF00402715

Brown, S. (2001), “Marketing for Muggles: Harry Potter and the retro-revolution”, Journal of Marketing Management, Vol. 17 Nos 5-6, pp. 463-479.

Brown, S., Kozinets, R.V. and Sherry, J.F. Jr (2003), “Teaching old brands new tricks: retro-branding and the revival of brand meaning”, Journal of Marketing, Vol. 67 No. 3, pp. 19-33.

Bruce, V., Green, Patrick R, & Georgeson, Mark A. (1996). *Visual perception : Physiology, psychology, and ecology / Vicki Bruce, Patrick R. Green, Mark A. Georgeson.* (3rd ed.). Hove, East Sussex, UK: Psychology Press.

Bryce, J. and Rutter, J. (2003) ‘Editorial comment’, Information Communication & Society, 6 (4): v– x.

Bushnell, N. (1999). "father of video game industry," joins MetaMarkets think tank, *Business Wire.*

Butler, A., Izadi, S., and Hodges, S. 2008. SideSight: multi- "touch" interaction around small devices. In Proceedings of the 21st Annual ACM Symposium on User interface Software and Technology (Monterey, CA, USA, October 19 - 22, 2008). UIST '08. ACM, New Yor**k**, NY, 201-204.

Cairns, P., Li, J., Wang, W., & Nordin, A. (2014). The influence of controllers on immersion in mobile games. Paper presented at the 371-380. doi:10.1145/2556288.2557345

Ceruzzi, P. E. (2005). Moore's law and technological determinism: Reflections on the history of technology. Technology and Culture, 46(3), 584-593.

Choe, P., & Schumacher, D. (2015). Influence of different types of vibrations on technical acceptance of a mobile game aiming for hedonic satisfaction. *International Journal of Human-Computer Interaction, 31*(1), 33-43. doi:10.1080/10447318.2014.959101

Cohen, D. J., Frisch, M., Gallagher, P., Mintz, S., Sword, K., Taylor, A. M., . . . Turkel, W. J. (2008). Interchange: The promise of digital history. The Journal of American History, 95(2), 452-491.

Colle, H. A., & Hiszem, K. J. (2004). Standing at a kiosk: Effects of key size and spacing on touch screen numeric keypad performance and user preference. *Ergonomics, 47*(13), 1406-1423.

Crilly, N., Moultrie, J., & Clarkson, P. J. (2009). Shaping things: Intended consumer response and the other determinants of product form. Design Studies, 30(3), 224-254.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16, 297–334.

Dandekar, K., Raju, B. I., & Srinivasan, M. A. (2003). 3-D finite-element models of human and monkey fingertips to investigate the mechanics of tactile sense. Journal of Biomechanical Engineering, 125(5), 682.

Darejeh. (2013). a review on user interface design principles to increase software usability for users with less computer literacy. *Journal of Computer Science, 9*(11), 1443-1450. doi:10.3844/jcssp.2013.1443.1450

Dell'Era, C. and Bellini, E. (2009), "How can product semantics be embodied in product technologies? The case of the Italian wine industry", International Journal of Innovation Management, Vol. 13 No. 3, pp. 411-439.

Dix, A. (2004). *Human-computer interaction / Alan Dix ... [et al.].* (3rd ed.). Harlow, England ; New York: Pearson/Prentice Hall.

Dreyfuss, H., 1904-1972. (2003). *Designing for people* Allworth Press.

Dzida, W. (1995). Standards for user-interfaces. *Computer Standards & Interfaces, 17*(1), 89-97. doi:10.1016/0920-5489(93)E0069-E

Edgecliffe-Johnson, A. (2007). Use of video and computer games declines among children: LONDON 1ST EDITION. *Financial Times*

Feki, M. A., Kawsar, F., Boussard, M., & Trappeniers, L. (2013). The internet of things: The next technological revolution. Computer, 46(2), 24-25.

Fitts, P. M. (1992). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology: General, 121(3), 262-269.

Fitzsimmons, J. (1994). Information technology and the third industrial revolution. The Electronic Library, 12(5), 295-297.

Giesler, Markus (2006). "Consumer Gift Systems". *Journal of Consumer Research* **33** (2): 283–290.

Gil, K., Rhim, J., Ha, T., Doh, Y. Y., & Woo, W. (2014). AR petite theater: Augmented reality storybook for supporting children's empathy behavior. Paper presented at the 13-20.

Hackos, J. T., & Redish, J. (1998). User and task analysis for interface design.

Hoggan, E., Brewster, S., & Johnston, J. (2008). Investigating the effectiveness of tactile feedback for mobile touchscreens. Paper presented at the 1573-1582. doi:10.1145/1357054.1357300

Hookway, Branden. Interface. Cambridge, MA, USA: The MIT Press, 2014. ProQuest ebrary. Web. 31 July 2015.

Hornbæk, K. (2006). Current practice in measuring usability: Challenges to usability studies and research. *International Journal of Human - Computer Studies, 64*(2), 79-102. doi:10.1016/j.ijhcs.2005.06.002

Hornbæk, K., & Law, E. (2007). Meta-analysis of correlations among usability measures. Paper presented at the 617-626. doi:10.1145/1240624.1240722

Huang, H. (2012). Enhancing touch feedback and visual search effects for touchscreen icon. *Journal of Convergence Information Technology, 7*(3), 233-240.

Huston, R. L. (1994). The measure of man and woman - human factors in design alvin R. tilley, henry dreyfuss associates 1993, 96 pages, $60.00 new york: Whitney library of design, watson-guptill ISBN 0-8230-3031-8. *Ergonomics in Design: The Quarterly of Human Factors Applications, 2*(2), 37-39.

Hutchins, E., Hollan, J., & Norman, D. (1985). Direct Manipulation Interfaces. Human-Computer Interaction, 1, 311-338. doi:10.1207/s15327051hci0104_2

Islam, N., & Want, R. (2014). Smartphones: Past, present, and future. IEEE Pervasive Computing, 13(4), 89-92.

Kim, Y. (2010). Oriental well-being design. Paper presented at the 286-289.

Kim, Y., & Choi, J. (2010). Interactive oriental orchid read with the spirit and mind. Paper presented at the 1-1.

Kim, Y., & Lee, J. (2015). Game interface enhancement under smartphone platform focused on touchscreen interaction. *Computers & Industrial Engineering, 80*, 45-61.

Klemmer, S., Hartmann, B., & Takayama, L. (2006). How bodies matter: Five themes for interaction design. Paper presented at the 140-149. doi:10.1145/1142405.1142429

Kwon, B. c., Javed, W., Elmqvist, N., & Yi, J. S. (2011). Direct manipulation through surrogate objects. Paper presented at the 627-636. doi:10.1145/1978942.1979033

Lin, Y., Chang, L., Lee, Y., Tseng, H., Kuo, T. B. J., & Chen, S. (2014). Development and validation of the smartphone addiction inventory (SPAI). *PloS One, 9*(6), e98312.

LukeW | Touch Gesture Reference Guide. (n.d.). Retrieved December 10, 2015, from http://www.lukew.com/touch/

Maddox, M. (2008). Pretty is as pretty does. *Industrial Engineer, 40*(9), 22.

Moggridge, B., & ebrary, I. (2007). Designing interactions MIT Press.

Myers, B. A., Nichols, J., Wobbrock, J. O., & Miller, R. C. (2004). Taking handheld devices to the next level. *Computer, 37*(12), 36-43.

Natapov, D., & MacKenzie, I. (2010). Gameplay evaluation of the trackball controller. Paper presented at the 167-174. doi:10.1145/1920778.1920802

Negroponte, N. (1995). Being digital (1st ed.) Knopf.

Nias, J. (2016). *Cultural similarities and differences in user-defined gestures for mobile interfaces*
Norman, Donald, A., & Pemberton, Steven. (1999). Affordance, conventions, and design. *Interactions, 6*(3), 38-43.

NIELSEN, J. (1993). is usability engineering really worth it. *Ieee Software, 10*(6), 90-92. doi:10.1109/MS.1993.10066

Norman, D. A. (1988). *The psychology of everyday things* Basic Books.

Norman, D. (2004). Introduction to this special section on beauty, goodness, and usability. *Human-Computer Interaction, 19*(4), 311-318.

Olwal, A., Feiner, S., & Heyman, S. (2008). Rubbing and tapping for precise and rapid selection on touch-screen displays. Paper presented at the 295-304. doi:10.1145/1357054.1357105

Oshita, M., & Ishikawa, H. (2012). Gamepad vs. touchscreen: A comparison of action selection interfaces in computer games. Paper presented at the 27-31. doi:10.1145/2425296.2425301

Pelegrino, M., Torok, L., Trevisan, D., & Clua, E. (2014). Creating and designing customized and dynamic game interfaces using smartphones and touchscreen. Paper presented at the 133-139. doi:10.1109/SBGAMES.2014.21

Pereira, L., & Roque, L. (2013). Gameplay experience evaluation centered on participation: The fátima game design case. Paper presented at the 1131-1136. doi:10.1145/2468356.2468558

Peters, J. D. (1999). Speaking into the air: A history of the idea of communication University of Chicago Press.

Prensky, M. (2001). *Digital game-based learning* McGraw-Hill.

Ranney, J. D., & Troop-Gordon, W. (2015). Problem-focused discussions in digital contexts: The impact of information and communication technologies on conversational processes and experiences. Computers in Human Behavior, 51, 64-74.

Reisberg, D. (2006). *Cognition : Exploring the science of the mind / Daniel Reisberg.* (3rd ed.). New York: W.W. Norton.

Roco, J., Corssnan, A., Brewster, S. (2011) Gesture-Based Interfaces: Practical Applications of Gestures in Real World Mobile Settings. Whole Body Interaction. London: Springer. pp. 173-186.

ROSLI, D. I. (2015). Cognitive awareness prototype development on user interface design. *TOJET : The Turkish Online Journal of Educational Technology, 14*(2)

Ryu, T. (2010). *Maum: Exploring immersive gameplay with emerging user interface devices*

Sanders, E. B. N. (1992). Converging perspectives: Product development research for the 1990s. Design Management Journal, 3(4), 49-54.

Saffer, D. (2007). Designing for interaction: Creating smart applications and clever devices New Riders.

Saffer, D. (2008). *Designing Gestural Interfaces: Touchscreensand InteractiveDevices. InteractiveGesturesDesigning GesturalInterfaces*(p. 272). O'ReillyMedia.

Saffer, D., & Ebooks Corporation. (2008). *Designing gestural interfaces* (1st ed.) O'Reilly.

Seel, P. B. (2012). Digital universe: The global telecommunication revolution Wiley-Blackwell.

Selber, S. (2004). Technological dramas: A meta-discourse heuristic for critical literacy1. *Computers and Composition, 21*(2), 171-196.

Sener, B., & Wormald, P. (2008). User evaluation of HCI concepts for defining product form. Design Studies, 29(1), 12-29.

Sethumadhavan, A. (2016). Five user interface design tenets. *Ergonomics in Design: The Quarterly of Human Factors Applications, 24*(2), 31-31. doi:10.1177/1064804616642740

Shackel, B. (2009). Usability – context, framework, definition, design and evaluation. *Interacting with Computers, 21*(5), 339-346. doi:10.1016/j.intcom.2009.04.007

Shneiderman, B. (1984). The future of interactive systems and the emergence of direct manipulation. Paper presented at the Proc. of the NYU symposium on user interfaces on Human factors and interactive computer systems, New York, USA.

Shneiderman, B. (1998). *Designing the user interface: Strategies for effective human-computer interaction* (3rd ed.) Addison-Wesley.

Siewiorek, D. (2002). New frontiers of application design. *Communications of the ACM, 45*(12), Communications of the ACM, Vol.45(12).

Stanton, Neville A. 1960- (Neville Anthony), & ebrary, I. (2005). *Human factors methods: A practical guide for engineering and design* Ashgate Pub. Co.

Stellmach, T., Leker, A., Lantz, F., Hunicke, R., Hocking, C., LeBlanc, M. Havens, J. (2010). The 10th annual game design.

Sony upgrades its play station 2. (2003,). *The New York Times.*

Sorman-Nilsson, Anders. Digilogue : How to Win the Digital Minds and Analogue Hearts of Tomorrow's Customer. Somerset, NJ, USA: John Wiley & Sons, 2013. ProQuest ebrary. Web. 30 July 2015.

Stalder, F. (1999). The control revolution: How the internet is putting individuals in charge and changing the world. ACM SIGCAS Computers and Society, 29(4), 38-39.

Steinkuehler, C., & Squire, K. (2009). Virtual worlds and learning. *On the Horizon, 17*(1), 8-11.

Tsagarakis, N. G., & Caldwell, D. G. (2013). Improving mouse-based computer interaction in users with weak upper limb motion control using a haptic assistive system. *IEEE Transactions on Human-Machine Systems, 43*(2), 177-187. doi:10.1109/TSMCC.2012.2204872

Teather, R., & MacKenzie, I. (2014). Comparing order of control for tilt and touch games. Paper presented at the 1-10. doi:10.1145/2677758.2677766

Utterback, J. M., 1941, & ebrary, I. (2006). Design-inspired innovation World Scientiific Pub.

Veryzer, R. (1993). The Place of Product Design and Aesthetics in Consumer Research. Retrieved November 10, 2016, from http://www.acrwebsite.org/volumes/7824/volumes/v22/NA-22

Vlieghe, J. (2014). Education in an age of digital technologies: Flusser, stiegler, and agamben on the idea of the posthistorical. Philosophy & Technology, 27(4), 519-537.

Vogel, D., & Baudisch, P. (2007). Shift: A technique for operating pen-based interfaces using touch. Paper presented at the 657-666. doi:10.1145/1240624.1240727

War and video games. (2011,). *The New York Times*

Williams, N., & Wilkinson, T. (1994). Experiences in writing a WYSIWYG editor for HTML. Computer Networks and ISDN Systems, 27(2), 310-311.

Wobbrock, J., Morris, M., & Wilson, A. (2009). User-defined gestures for surface computing. Paper presented at the 1083-1092. doi:10.1145/1518701.1518866

Xenakis, I., & Arnellos, A. (2013). The relation between interaction aesthetics and affordances. Design Studies, 34(1), 57-73.

Xiong, J., & Muraki, S. (2014). An ergonomics study of thumb movements on smartphone touch screen. *Ergonomics, 57*(6), 943-955.

Yalch, R. & Brunel, F. (1996), Need hierarchies in consumer judgements of product designs: is it time to reconsider Maslow's theory?, Advances in Consumer Research, 23, pp. 405–410.

Young, S. (2010). Cognitive user interfaces. *IEEE Signal Processing Magazine, 27*(3), 128-140.

Zaman, L., Natapov, D., & Teather, R. (2010). Touchscreens vs. traditional controllers in handheld gaming. Paper presented at the 183-190. doi:10.1145/1920778.1920804

Web & Media Resources:

A Dictionary of information acronyms. (n.d.). Retrieved November 2, 2015 from http://www.itgovernance.co.uk/files/9781905356218-v1.pdf

A History of Video Game Consoles. (n.d.). Retrieved October 16, 2015, from http://content.time.com/time/interactive/0,31813,2029221,00.html

Analog vs. Digital. (n.d.). Retrieved August 2, 2015, from http://www.diffen.com/difference/Analog_vs_Digital#Definitions_of_Analog_vs._Digital_signals

App Store Metrics. (n.d.). Retrieved October 24, 2015, from http://www.pocketgamer.biz/metrics/app-store/

Audio Cabinet Power - AVS Forum | Home Theater Discussions And Reviews. (n.d.). Retrieved October 18, 2015, from http://www.avsforum.com/forum/32-theater-room-items-accessories/2009722-audio-cabinet-power.html

Ayers, E.L., (1999). The Pasts and Futures of Digital History, Retrieved October 17, 2015, from http://www.vcdh.virginia.edu/PastsFutures.html

A procedure for developing Intuitive and Ergonomic Gesture Interfaces for Man-Machine Interaction. (2003, March 1). Retrieved October 23, 2015, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.2.2114&rep=rep1&type=pdf

Brookhaven National Laboratory (n.d.) 'Video games – did they begin at Brookhaven?', retrieved 02 October 2015 from: http://www.osti.gov/accomplishments/videogame.html

Cardinal, D. (2011, October 11). From punchcards to Siri: The history (and future) of input devices - Slideshow | ExtremeTech. Retrieved August 10, 2015, from http://www.extremetech.com/computing/98287-from-punchcards-to-ipads-the-history-of-input-devices

Chapter 2. History: A Brief History of User Interfaces. (n.d.). Retrieved October 17, 2015, from http://www.catb.org/esr/writings/taouu/html/ch02.html

Chen, C., Huang, T., Park, J. J., & Yen, N. Y. (2015; 2013). Real-time smartphone sensing and recommendations towards context-awareness shopping. Multimedia Systems, 21(1), 61-72.

Christensen, C. M., & NetLibrary, I. (1997). The innovator's dilemma: When new technologies cause great firms to fail Harvard Business School Press.

Consolidated Sales Transition by Region. (n.d.). Retrieved October 16, 2015, from http://www.nintendo.co.jp/ir/library/historical_data/pdf/consolidated_sales_e1503.pdf

Control Knob (n.d.). Retrieved October 18, 2015, from https://en.wikipedia.org/wiki/Control_knob

DIFFERENT SENSOR TYPES. (n.d.). Retrieved October 17, 2015, from http://world.wikomobile.com/a1062-DIFFERENT-SENSOR-TYPES

Digital - definition of digital in English from the Oxford ... (n.d.). Retrieved November 2, 2015 from http://www.oxforddictionaries.com/definition/english/digital

Digital Revolution (n.d.). Retrieved October 17, 2015, from http://en.wikipedia.org/wiki/Digital_Revolution

Dwell magazine's interview with Fukasawa, "Without a Trace," by Jane Szita, September 2006, Retrieved October 18, 2015, from http://www.dwell.com/peopleplaces/profiles/3920931/html

Evolution of Video Games User Interface (UI). (n.d.). Retrieved October 17, 2015, from http://www.hongkiat.com/blog/video-games-ui-evolution/

Evolution of Video Game Controllers-Stanford University.(n.d.). Retrieved from http://web.stanford.edu/group/htgg/cgi-bin/drupal/sites/default/files2/wlu_2003_1.pdf

Evolution of Video Games User Interface (UI). (n.d.). Retrieved October 17, 2015, from http://www.hongkiat.com/blog/video-games-ui-evolution/

Gartner Your Source for Technology Research and Insight. (n.d.). Retrieved October 16, 2015, from http://www.gartner.com/technology/home.jsp

Gibson, J. (1979). *The ecological approach to visual perception / James J. Gibson.* Boston: Houghton Mifflin.

Greeno, J., & Kintsch, Walter. (1994). Gibson's Affordances. *Psychological Review, 101*(2), 336-342.

Guide to Control Surfaces. (n.d.). Retrieved October 18, 2015, from http://tweakheadz.com/control-surfaces/

History of the graphical user interface (n.d.). Retrieved October 17, 2015, from https://en.wikipedia.org/wiki/History_of_the_graphical_user_interface#cite_note-1

History of iPod (n.d.). Retrieved October 17, 2015, from https://en.wikipedia.org/wiki/IPod

Interaction Design Foundation. (n.d.). Retrieved October 23, 2015 from http://www.interaction-design.org/encyclopedia/industrial_design.html

Knobs and Dials in Mobile App Interfaces - Designmodo. (2013, August 6). Retrieved October 18, 2015, from http://designmodo.com/knobs-dials-mobile-app/

Knobs | Skill Type | Ui Parade. (n.d.). Retrieved October 18, 2015, from http://www.uiparade.com/skill-type/knobs/

Korea Today: Marriage of digital and analog worlds by Arirang Issue. (n.d.). Retrieved October 17, 2015, from https://www.youtube.com/watch?v=2WgtkOxJpMU

Kshama Solutions. (n.d.). Retrieved October 17, 2015, from http://kshamasolutions.com/

Mobile Game (n.d.). Retrieved October 17, 2015, from https://en.wikipedia.org/wiki/Mobile_game.

MOGA Power Smartphone Game Controllers - MIKESHOUTS. (2013, November 5). Retrieved October 17, 2015, from http://mikeshouts.com/moga-power-smartphone-game-controllers/

Money-Shredding Alarm Clock Is Completely Unforgiving [PICS]. (n.d.). Retrieved October 17, 2015, from http://mashable.com/2011/05/29/money-shredding-alarm/

Native Union POP Desk V2, Pop Phone with Metal Stand. (n.d.). Retrieved October 17, 2015, from http://www.kathyirelandconnect.com/collections/home-office/products/native-union-pop-desk-v2

LG's leather-clad G4 revealed in leaked images. (2015, April 12). Retrieved October 17, 2015, from http://www.theverge.com/2015/4/12/8392877/lg-g4-pictures-leaked

PINTO. (n.d.). Retrieved October 17, 2015, from http://www.pinto-design.jp/works/index_eng.html

Realizing Potential of Mobile Gaming. (2009). Retrieved October 27, 2015, from http://www.gsma.com/membership/wp-content/uploads/2012/03/Comviva_WP_MobileGaming.pdf

Report: Mobile to become gaming's biggest market by 2015. (n.d.). Retrieved October 17, 2015, from http://www.gamesindustry.biz/articles/2014-10-22-report-mobile-to-become-gamings-biggest-market-by-2015.

Review: Apple iPhone 6 Plus. (2014, October 3). Retrieved October 17, 2015, from http://www.tabletsmagazine.nl/2014/10/review-apple-iphone-6-plus/

Robot Check. (n.d.). Retrieved December 27, 2015, from http://www.amazon.com/Ecsem-Fling-Joystick-Controller-Suction/dp/B00D5PQ1SW/ref=sr_1_1?s=pc&ie=UTF8&qid=1451172886&sr=1-1&keywords=The Fling Mini

Robot Check. (n.d.). Retrieved December 27, 2015, from http://www.amazon.com/SmartTACT-Smartphone-Controller-Joystick-Emulators/dp/B010OWPFHQ

Sales, Demographic, and Usage Data Essential Facts. (n.d.). Retrieved from http://www.theesa.com/wp-content/uploads/2015/10/ESA_EF_2014.pdf

Shape Up Alarm Clock Dumbbell to wake masochists. (n.d.). Retrieved October 17, 2015, from http://www.gizmag.com/shape-up-alarm-clock-dumbbell/12149/

Smartphone (n.d.). Retrieved October 17, 2015, from https://en.wikipedia.org/wiki/Smartphone

Time Switch Wall Clock Is Perfect For Proctastinators With Great Imaginations. (2009, July 16). Retrieved October 17, 2015, from http://www.ohgizmo.com/2009/07/16/time-switch-wall-clock-is-perfect-for-proctastinators-with-great-imaginations/

Top 10: Cool gadget accessories. (n.d.). Retrieved October 17, 2015, from http://www.ibnlive.com/photogallery/tech/top-10-cool-gadget-accessories-807047.html

Touch Fighter - Full Korean Fighting. (n.d.). Retrieved October 17, 2015, from http://app4smart.com/en/912-touch-fighter.html

Topols**k**y, J., 2009, Live from Apple's 'It's only roc**k** and roll' event, Engadget,

http://www.engadget.com/2009/09/09/livefrom-
apples-its-only-rock-and-roll-event/, Access date: February 6, 2010

User Experience Basics. (n.d.). Retrieved October 17, 2015, from http://www.usability.gov/what-and-why/user-experience.html

Vehicle Audio (n.d.). Retrieved October 18, 2015, from https://en.wikipedia.org/wiki/Vehicle_audio

Wake'n Bacon - The Real Bacon Alarm Clock - Bacon Today. (2011, May 25). Retrieved October 17, 2015, from http://bacontoday.com/waken-bacon-the-real-bacon-alarm-clock/

Wire 3 Way Light Switch - Electricians - Talk Local Blog. (n.d.). Retrieved October 18, 2015, from http://www.talklocal.com/blog/2013/06/s/electricians/wire-3-way-light-switch/

WoW subscription number 2015 | Statistic. (n.d.). Retrieved October 16, 2015, from http://www.statista.com/statistics/276601/number-of-world-of-warcraft-subscribers-by-quarter/

'WynCASE' (n.d.). Retrieved October 23, 2015, from http://kr.aving.net/news/view.php?articleId=460423&Branch_ID=kr&rssid=naver&mn_name=news

2015 Global Games Market Report | Newzoo. (n.d.). Retrieved October 17, 2015, from http://www.newzoo.com/product/2015-global-games-market-report/

$6,000 Bang & Olufsen System Features Pandora-like Music Analysis. (n.d.). Retrieved October 17, 2015, from http://www.wired.com/2009/02/bang-olufsens-b/

APPENDIX A

INFORMED CONSENT DOCUMENT

Title of Study: **Usability Evaluation for Gaming Control Interface on Smartphone**
Participants: Principle Investigator: Sang-Duck Seo
Faculty Supervisor: Sunghyun Kang, BFA, MA, MFA
This test is a usability study on gaming control interface. Please take your time in deciding if you would like to participate in this usability test. Please also feel free to ask questions at any time. No items will be purchased during the session. No personal or financial information will be collected during the session.

INTRODUCTION

The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. Finding problems in **playing a game with touchscreen interface** will be the primary focus of this study.

This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games. This usability study will help the gaming industry, game developers, and UX/UI designers to improve or develop smartphone products.

Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve the usability of the interface system for the general public.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, participation will last approximately 60 minutes.

During the study, you may expect the following study procedures to be followed.

1) The researcher will contact prospective participants to schedule a usability study and will send informed consent document.

2) On the selected date of the usability study, you will be given a copy of the Informed Consent Document for review and to sign prior to the start of the session. If you agree, and sign the Informed Consent Document, the session will begin.

3) Information regarding the project will be read before the session.

4) The respondent will complete the pre-survey questionnaire regarding demographic information and their familiarity with the technologies.

5) The usability testing will take place at GRA 241 at University of Nevada Las Vegas. Your voice and/or video will be recorded during the test. Your hand(s) and finger(s) movement will be also recorded during playing a game. You will not be identified in any future video use (i.e. video will not include your face).

6) The participants will perform a series of tasks on the interface design of playing a smartphone game. You may skip any tasks that you do not wish to perform or that makes you feel uncomfortable.

7) The participants will complete a brief exit survey and interview after the usability testing.

RISKS
There are no foreseeable risks in this study. However, you may leave the study at any time without penalty.
BENEFITS
Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve interface design for smartphone products.

COSTS AND COMPENSATION
You will not have any costs from participating in this study. There will not be any compensation to participate in this study.
PARTICIPANT RIGHTS
Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide not to participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled. During the testing, if you feel uncomfortable at anytime you can quit.

CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken.

The participant's identity will be anonymous to outside sources throughout the study. Only the researchers will have access to the data. The data will be entered and kept in the Principal Investigator (PI)'s computer with a password protected. Any field notes taken during this study will not contain the names of the participants. Questionnaires and field notes will be shredded after all the information is entered into the computer. Any video/audio files may be retained for future use pertaining to this research, however videos will not contain any identifying information, such as the participants name, nor will the video include the participants face. If video that is recorded contains any identifying marks (e.g. tattoos, scars), these marks will be blurred on the permanent video file attached to the research. Once the study has been concluded, all data files may be retained for future use pertaining to this research process.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study. For further information about the study contact Sunghyun Kang, Supervisor, phone 515-294-1669, email shrkang@iastate.edu or Principal Investigator, Sang-Duck Seo, phone 702-895-2719, email sdseo@iastate.edu.
If you have any questions about the rights of research subjects or research-related injury, please contact IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, Office for Responsible Research, (515) 294-3115, 1138 Pearson Hall, Ames, IA 50011.
****
SUBJECT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily

answered. You will receive a copy of the signed and dated written informed consent prior to your participation in the study.

Subject's Name (printed) ____

____________________________________ ________________

(Subject's Signature) (Date)

APPENDIX B

IRB EXEMPT APPROVAL DOCUMENT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 11/24/2015

To: Dr. Sang-Duck Seo
2656 Rue Montpellier Ave.
Henderson, NV 89044

CC: Dr. Sunghyun Kang
282 Design

From: Office for Responsible Research

Title: Usability Evaluation for Gaming Control Interface on Smartphone

IRB ID: 15-596

Approval Date: 11/23/2015 **Date for Continuing Review:** 11/22/2017

Submission Type: New **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp**.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX C

PARTICIPANTS RECRUITMENT FLYER

PARTICIPANTS NEEDED To Test Usability

Are you over 18 years old?
Have you experienced <u>playing a game on a smartphone?</u>
Are you willing to spend approximately 60 minutes to test an interface to improve its usability?

If you are interested in participating in this study, please contact Sang-Duck Seo via <u>sang-duck.seo@unlv.edu</u>

sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu

APPENDIX D

WORD OF MOUTH SCRIPT FOR PARTICIPANT RECRUITMENT

I am looking for participants for interface usability study on the gaming control interface. This test is to improve user interface (UI) and experience design (UX) in playing a game on a smartphone. A participant will play a given smartphone game by touch screen and with a game controller. The process will be videotaped while a participant is conducting a task in the usability test. The usability study can be done in 60 minutes at your convenience at GRA 241 at University of Nevada Las Vegas.

Participation is completely voluntary. All of the information participants provide will be kept strictly confidential and reported in summary form only. No individual will be identified, nor will participants' names be attached to any data. At the project's end, researchers will destroy any identifying personal information.

If you or you also know someone over 18 years old who has experienced playing a game on a smartphone may be interested in participating this study, please contact me via sang-duck.seo@unlv.edu,

Sang-Duck Seo

APPENDIX E

EMAIL SCRIPT FOR PARTICIPANT RECRUITMENT

Dear _________,

Thank you very much for your participating in the research project.
I am looking for participants for interface usability study on the gaming control interface. This test is to improve user interface (UI) and experience design (UX) in playing a game on a smartphone. A participant will play a given smartphone game by touchscreen and with a game controller. The process will be videotaped while a participant is conducting a task in the usability test. The usability study can be done in 60 minutes at your convenience at my office, GRA 241 at University of Nevada Las Vegas.

Participation is completely voluntary. All of the information participants provide will be kept strictly confidential and reported in summary form only. No individual will be identified, nor will participants' names be attached to any data. At the project's end, researchers will destroy any identifying personal information.

Would you be willing to spend approximately 60 minutes participating in a usability study of an interface? If yes, please respond to this email if you are over 18 years old who have experienced playing a game on smartphone. I will email you an informed consent document for you to review and set up a convenient time for the testing. The informed consent document will be provided at the test site for your signature.

Again, you may choose to withdraw from participating at any time without penalty.
If you have any questions or concerns, feel free to contact me anytime via sang-duck.seo@unlv.edu
Thank you for your time and consideration.

Sincerely,

Sang-Duck Seo
HCI Ph.D Student
Iowa State University

APPENDIX F

SCRIPT FOR INTRODUCING A USABILITY TEST

My name is Sang-Duck Seo

Thank you very much for your participations to contribute to the interface usability study on the gaming control interface. This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games.

The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. You will play a given game up to 5 minutes per each game, but the game may be over in 5 minutes if you are not able to succeed on each level/task.

Your participation will contribute to improving the usability of the interface design. You will be asked to read and sign the Informed Consent Document.
This study will consist of three stages: 1) filling out the user information, 2) conducting tasks, and 3) filling out the exit survey and discuss open-ended questions.

This study will take approximately 60 minutes.

You will have a short demo instruction as to how to play a game before the test begins. If you have any questions during a demo instruction, please let me know.

APPENDIX G

SURVEY FOR PARTICIPANT INFORMATION

1. Age

❑ 18- 23 ❑ 24-29 ❑ 30-35 ❑ 36-41
❑ 42- 47 ❑ 48-53 ❑ 54-59 ❑ 60-65 ❑ 65+

2. Gender

❑ Male ❑ Female

3. Native language

❑ English ❑ Other (Please specify:)

4. Education

❑ High school ❑ Undergraduate student
❑ College Graduate ❑ Advanced Degree
❑ Others (Please specify:)

6. How comfortable are you using the following:

Computer:
❑ Uncomfortable ❑ Slightly Uncomfortable ❑ Slightly Comfortable ❑ Comfortable ❑ Don't Use

Tablets (iPads, Android Tablets):
❑ Uncomfortable ❑ Slightly Uncomfortable ❑ Slightly Comfortable ❑ Comfortable ❑ Don't Use

Smartphones:
❑ Uncomfortable ❑ Slightly Uncomfortable ❑ Slightly Comfortable ❑ Comfortable ❑ Don't Use

7. What kind of computer do you use?
❑ Macintosh ❑ PC (Dell, HP, IBM, Sony, Asus, Gateway, e-Machine, etc.) ❑ Others

8. What kind of smartphone do you use?
❑ iOS (Apple) ❑ Android ❑ Window Phone ❑ Others

9. How often do you use the following?

Computer:
❑ Less than Monthly ❑ Monthly ❑ Weekly ❑ Daily ❑ Never

Smartphone game:
❑ Less than Monthly ❑ Monthly ❑ Weekly ❑ Daily ❑ Never

Video/PC Game:
❑ Less than Monthly ❑ Monthly ❑ Weekly ❑ Daily ❑ Never

APPENDIX H

PILOT STUDY TASKS

GROUP A

Task List:

1. Play listed games (A-B-C) on the smartphone touch screen.
    1.1. Open a given game (A) on the smartphone.
    1.2. Begin playing the game.
    1.3. After the game over, create a profile.
    1.4. Open a given game (B) on the smartphone.
    1.5. Begin playing the game.
    1.6. After the game over, create a profile.
    1.7. Open a given game (C) on the smartphone.
    1.8. Begin playing the game.
    1.9. After the game over, create a profile.

2. Play listed games (A-B-C) on the smartphone with a game controller.
    2.1. Open a given game (A) on the smartphone.
    2.2. Begin playing the game.
    2.3. After the game over, create a profile.
    2.4. Open a given game (B) on the smartphone.
    2.5. Begin playing the game.
    2.6. After the game over, create a profile.
    2.7. Open a given game (C) on the smartphone.
    2.8. Begin playing the game.
    2.9. After the game over, create a profile.

Note:

Participants will conduct three different genres of smartphone games.

A. Causal game: PacMan (Movement only)
B. Arcade Game: Meganoid (Movement & Jumping)
C. Action game: AirAttack (Movement & Shooting)

GROUP B

Task List:

1. Play listed games (A-B-C) on the smartphone with a game controller.
    1.1. Open a given game (A) on the smartphone.
    1.2. Begin playing the game.
    1.3. After the game over, create a profile.
    1.4. Open a given game (B) on the smartphone.
    1.5. Begin playing the game.
    1.6. After the game over, create a profile.
    1.7. Open a given game (C) on the smartphone.
    1.8. Begin playing the game.
    1.9. After the game over, create a profile.

2. Play listed games (A-B-C) on the smartphone touch screen.
    2.1. Open a given game (A) on the smartphone.
    2.2. Begin playing the game.
    2.3. After the game over, create a profile.
    2.4. Open a given game (B) on the smartphone.
    2.5. Begin playing the game.
    2.6. After the game over, create a profile.
    2.7. Open a given game (C) on the smartphone.
    2.8. Begin playing the game.
    2.9. After the game over, create a profile.

Note:
Participants will conduct three different genres of smartphone games.

A. Causal game: PacMan (Movement only)
B. Arcade Game: Meganoid (Movement & Jumping)
C. Action game: AirAttack (Movement & Shooting)

APPENDIX I

EXIT SURVEY

Q1. On Touchscreen

			1	2	3	4	5	
1.	Overall, how easy was it to control the game interface by the touchscreen?	Easy						Difficult
2.	Overall, how easy was it to control the directed movement by the touchscreen?	Easy						Difficult
3.	Overall, how easy was it to control actions such as jump and shooting by the touchscreen?	Easy						Difficult
4.	Overall, how easy was it to look at the screen during playing a game?	Easy						Difficult
5.	Overall, how comfortable was it to hold the smartphone during playing a game?	Comfort						Discomfort

Q2. On Game Controller

			1	2	3	4	5	
1.	Overall, how easy was it to control the game interface by the game controller?	Easy						Difficult
2.	Overall, how easy was it to control the directed movement by the game controller?	Easy						Difficult
3.	Overall, how easy was it to control actions such as jump and shooting by the game controller?	Easy						Difficult
4.	Overall, how easy was it to look at the screen during playing a game?	Easy						Difficult
5.	Overall, how comfortable was it to hold the game controller during playing a game?	Comfort						Discomfort

Q3. Comparisons

		Touchscreen	Game controller	Both	None
1.	Which performance was easier to control the game interface?				
2.	Which performance was easier to control the directed movement?				
3.	Which performance was easier to control actions such as jump and?				
4.	Which performance was easier to look at the screen during playing a game?				
5.	Which device was more comfortable to hold during playing a game?				

Open-Ended Questions:

Have you played any games similar to A, B, or C? If yes, what platform was your experience (PC, Smartphone, Video game, etc.)?

Have you experienced playing any games with game controllers? If yes, what type of game controller(s) was it?

Which game was the most comfortable to play on the touchscreen? And why?

Which game was the most frustrating to play on the touchscreen? And why?

Which game was the most comfortable to play with the game controller? And why?

Which game was the most frustrating to play with the game controller? And why?

What did you like most about playing a game on the touchscreen?

What did you like most about playing a game on the game controller?

What did you find most frustrating about using the touchscreen?

What did you find most frustrating about using the game controller?

Additional comments:

APPENDIX J

REVISED INFORMED CONSENT DOCUMENT

Title of Study: **Usability Evaluation for Gaming Control Interface on Smartphone**
Participants: Principle Investigator: Sang-Duck Seo
Faculty Supervisor: Sunghyun Kang, BFA, MA, MFA
This test is a usability study on gaming control interface. Please take your time in deciding if you would like to participate in this usability test. Please also feel free to ask questions at any time. No items will be purchased during the session. No personal or financial information will be collected during the session.

INTRODUCTION

The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. Finding problems in **playing a game with touchscreen interface** will be the primary focus of this study.

This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games. This usability study will help the gaming industry, game developers, and UX/UI designers to improve or develop smartphone products.
Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve the usability of the interface system for the general public.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, participation will last approximately 30 minutes.

During the study, you may expect the following study procedures to be followed.

1) The researcher will contact prospective participants to schedule a usability study and will send informed consent document.
2) On the selected date of the usability study, you will be given a copy of the Informed Consent Document for review and to sign prior to the start of the session. If you agree, and sign the Informed Consent Document, the session will begin.
3) Information regarding the project will be read before the session.
4) The respondent will complete the pre-survey questionnaire regarding demographic information and their familiarity with the technologies.
5) The usability testing will take place at GRA 241 at University of Nevada Las Vegas. Your voice and/or video will be recorded during the test. Your hand(s) and finger(s) movement will be also recorded during playing a game. You will not be identified in any future video use (i.e. video will not include your face).
6) The participants will perform a series of tasks on the interface design of playing a smartphone game. You may skip any tasks that you do not wish to perform or that makes you feel uncomfortable.
7) The participants will complete a brief exit survey and interview after the usability testing.

RISKS
There are no foreseeable risks in this study. However, you may leave the study at any time without penalty.

BENEFITS
Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve interface design for smartphone products.

COSTS AND COMPENSATION
You will not have any costs from participating in this study. There will not be any compensation to participate in this study.

PARTICIPANT RIGHTS
Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide not to participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled. During the testing, if you feel uncomfortable at anytime you can quit.

CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.
To ensure confidentiality to the extent permitted by law, the following measures will be taken.
The participant's identity will be anonymous to outside sources throughout the study. Only the researchers will have access to the data. The data will be entered and kept in the Principal Investigator (PI)'s computer with a password protected. Any field notes taken during this study will not contain the names of the participants. Questionnaires and field notes will be shredded after all the information is entered into the computer. Any video/audio files may be retained for future use pertaining to this research, however videos will not contain any identifying information, such as the participants name, nor will the video include the participants face. If video that is recorded contains any identifying marks (e.g. tattoos, scars), these marks will be blurred on the permanent video file attached to the research. Once the study has been concluded, all data files may be retained for future use pertaining to this research process.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study. For further information about the study contact Sunghyun Kang, Supervisor, phone 515-294-1669, email shrkang@iastate.edu or Principal Investigator, Sang-Duck Seo, phone 702-895-2719, email sdseo@iastate.edu.
If you have any questions about the rights of research subjects or research-related injury, please contact IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, Office for Responsible Research, (515) 294-3115, 1138 Pearson Hall, Ames, IA 50011.
****

SUBJECT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the signed and dated written informed consent prior to your participation in the study.

Subject's Name (printed) ____

____ ______________________

(Subject's Signature) (Date)

GROUP E-1:

Title of Study: **Usability Evaluation for Gaming Control Interface on Smartphone**
Participants: Principle Investigator: Sang-Duck Seo
Faculty Supervisor: Sunghyun Kang, BFA, MA, MFA
This test is a usability study on gaming control interface. Please take your time in deciding if you would like to participate in this usability test. Please also feel free to ask questions at any time. No items will be purchased during the session. No personal or financial information will be collected during the session.

INTRODUCTION
The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. Finding problems in **playing a game with touchscreen interface** will be the primary focus of this study.

This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games. This usability study will help the gaming industry, game developers, and UX/UI designers to improve or develop smartphone products.
Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve the usability of the interface system for the general public.

DESCRIPTION OF PROCEDURES
If you agree to participate in this study, participation will last approximately 45 minutes.

During the study, you may expect the following study procedures to be followed.

1) The researcher will contact prospective participants to schedule a usability study and will send informed consent document.

2) On the selected date of the usability study, you will be given a copy of the Informed Consent Document for review and to sign prior to the start of the session. If you agree, and sign the Informed Consent Document, the session will begin.
3) Information regarding the project will be read before the session.
4) The respondent will complete the pre-survey questionnaire regarding demographic information and their familiarity with the technologies.
5) The usability testing will take place at GRA 241 at University of Nevada Las Vegas. Your voice and/or video will be recorded during the test. Your hand(s) and finger(s) movement will be also recorded during playing a game. You will not be identified in any future video use (i.e. video will not include your face).
6) The participants will spend an extra 15 minutes for pre-exercise before the actual test. During 15 minutes, you will practice the given game to become familiar with playing methods.
7) The participants will perform a series of tasks on the interface design of playing a smartphone game. You may skip any tasks that you do not wish to perform or that makes you feel uncomfortable.
8) The participants will complete a brief exit survey and interview after the usability testing.

RISKS

There are no foreseeable risks in this study. However, you may leave the study at any time without penalty.

BENEFITS

Participants will not get direct benefits. However, this knowledge can be expected to provide ultimately significant opportunities to improve interface design for smartphone products.

COSTS AND COMPENSATION

You will not have any costs from participating in this study. There will not be any compensation to participate in this study.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide not to participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled. During the testing, if you feel uncomfortable at anytime you can quit.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken.

The participant's identity will be anonymous to outside sources throughout the study. Only the researchers will have access to the data. The data will be entered and kept in the Principal Investigator (PI)'s computer with a password protected. Any field notes taken during this study will not contain the names of the participants. Questionnaires and field notes will be shredded after all the information is entered into the computer. Any video/audio files may be retained for future use pertaining to this research, however videos will not contain any identifying information, such as the participants name, nor will the video include the participants face. If video that is recorded contains any identifying marks (e.g. tattoos, scars), these marks will be blurred on the permanent video file attached to the research. Once the study has been concluded, all data files may be retained for future use pertaining to this research process.

QUESTIONS OR PROBLEMS

You are encouraged to ask questions at any time during this study. For further information about the study contact Sunghyun Kang, Supervisor, phone 515-294-1669, email shrkang@iastate.edu or Principal Investigator, Sang-Duck Seo, phone 702-895-2719, email sdseo@iastate.edu.
If you have any questions about the rights of research subjects or research-related injury, please contact IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, Office for Responsible Research, (515) 294-3115, 1138 Pearson Hall, Ames, IA 50011.

****

SUBJECT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the signed and dated written informed consent prior to your participation in the study.

Subject's Name (printed) ____

______________________________________   ______________________

(Subject's Signature)   (Date)

APPENDIX K

IRB EXEMPT APPROVAL DOCUMENT FOR MODIFICATION FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date:	3/16/2016
To:	Sang-Duck Seo Montpellier 2656 Rue Ave. Henderson, NV 89044
From:	Office for Responsible Research
Title:	Usability Evaluation for Gaming Control Interface on Smartphone
IRB ID:	15-596

Approval Date:	3/16/2016	**Date for Continuing Review:**	11/22/2017
Submission Type:	Modification	**Review Type:**	Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX L

PARTICIPANTS RECRUITMENT FLYER FOR MAIN STUDY

PARTICIPANTS NEEDED To Test Usability

Are you over 18 years old?
Have you experienced <u>playing a game on a smartphone or PC Tablet?</u>
Are you willing to spend approximately 30 minutes to test an interface to improve its usability?

If you are interested in participating in this study, please contact Sang-Duck Seo via <u>sang-duck.seo@unlv.edu</u>

sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu	sang-duck.seo@unlv.edu

APPENDIX M

WORD OF MOUTH SCRIPT FOR PARTICIPANT RECRUITMENT OF MAIN STUDY

I am looking for participants for interface usability study on the gaming control interface. This test is to improve user interface (UI) and experience design (UX) in playing a game on a smartphone. A participant will play a given smartphone game by touch screen and with a game controller. The process will be videotaped while a participant is conducting a task in the usability test. The usability study can be done in 30 minutes at your convenience at GRA 241 at University of Nevada Las Vegas.

Participation is completely voluntary. All of the information participants provide will be kept strictly confidential and reported in summary form only. No individual will be identified, nor will participants' names be attached to any data. At the project's end, researchers will destroy any identifying personal information.

If you or you also know someone over 18 years old who has experienced playing a game on a smartphone may be interested in participating this study, please contact me via sang-duck.seo@unlv.edu,

Sang-Duck Seo

APPENDIX N

EMAIL SCRIPT FOR PARTICIPANT RECRUITMENT OF MAIN STUDY

Note: This script is to respond to an email from potential participants who informs their interest in participating in the usability study.

Dear _________,

Thank you very much for your responding in regards to your interest in participating for the research project. I am looking for participants for interface usability study on the gaming control interface. This test is to improve user interface (UI) and experience design (UX) in playing a game on a smartphone. A participant will play a given smartphone game by touchscreen and with a game controller. The process will be videotaped while a participant is conducting a task in the usability test. The usability study can be done in 30 minutes at your convenience at my office, GRA 241 at University of Nevada Las Vegas.

Participation is completely voluntary. All of the information participants provide will be kept strictly confidential and reported in summary form only. No individual will be identified, nor will participants' names be attached to any data. At the project's end, researchers will destroy any identifying personal information.

Would you be willing to spend approximately 30 minutes participating in a usability study of an interface? If yes, please respond to this email if you are over 18 years old who have experienced playing a game on smartphone. I will email you an informed consent document for you to review and set up a convenient time for the testing. The informed consent document will be provided at the test site for your signature.

Again, you may choose to withdraw from participating at any time without penalty.
If you have any questions or concerns, feel free to contact me anytime via sang-duck.seo@unlv.edu
Thank you for your time and consideration.

Sincerely,

Sang-Duck Seo
HCI Ph.D Student
Iowa State University

Note: This script is to recruit participants for the particular group that will conduct the usability study longer than other groups. An email responds to potential participants who informs their confirmation of participating in the usability study.

Dear _________,

Thank you very much for your confirmation in participating in the research project. Your participation will be a welcome contribution to this study's success.

However, I am also looking for participants who are willing to spend extra time on different conditions in playing a game. It will be an extra 15 minutes for pre-exercise before the actual test. During 15 minutes, you will practice the given game to be familiar with playing methods. If you are willing to be part of this condition, please respond to this email, so I can set up a total duration of 45 minutes.

Again, you may choose to withdraw from participating at any time without penalty.
If you have any questions or concerns, feel free to contact me anytime via sang-duck.seo@unlv.edu
Thank you for your time and consideration.

Sincerely,

Sang-Duck Seo
HCI Ph.D Student
Iowa State University

APPENDIX O

SCRIPT FOR INTRODUCING A USABILITY TEST ON MAIN STUDY

GROUP A-D, E-H
My name is Sang-Duck Seo

Thank you very much for your participations to contribute to the interface usability study on the gaming control interface. This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games.
The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. You will play a given game up to 10 minutes, but the game may be over in 10 minutes if you are not able to succeed on each level/task.
Your participation will contribute to improving the usability of the interface design. You will be asked to read and sign the Informed Consent Document.
This study will consist of three stages: 1) filling out the user information, 2) conducting tasks, and 3) filling out the exit survey and discuss open-ended questions.
This study will take approximately 30 minutes.
You will have a short demo instruction as to how to play a game before the test begins. If you have any questions during a demo instruction, please let me know.

GROUP E-1
My name is Sang-Duck Seo
Thank you very much for your participations to contribute to the interface usability study on the gaming control interface. This study aims to evaluate participants' satisfactory level, mistakes, and accuracy through the comparisons of user interfaces between digital and analog controller in smartphone games.
The primary objective is to discover an efficient input usability of an analog control interface on smartphone gaming environment. Before you conduct the usability test, you will have 15 minutes to have pre-exercise for playing a game with a game controller. During this exercise, you are free to ask any questions regarding games and/or controller.
After completing the pre-exercise, you are going to move onto the actual test. You will play a given game for up to 15 minutes, but the game may be over in 15 minutes if you are not able to succeed on each level/task.
Your participation will contribute to improving the usability of the interface design. You will be asked to read and sign the Informed Consent Document.
This study will consist of three stages: 1) filling out the user information, 2) conducting tasks, and 3) filling out the exit survey and discuss open-ended questions.
This study will take approximately 45 minutes.
You will have a short demo instruction as to how to play a game before the test begins. If you have any questions during a demo instruction, please let me know.

APPENDIX P

MAIN STUDY TASKS

GROUP A, B, C, AND D (ONE HAND INPUT CONTROL)

Task List:

1. Play a given game on the smartphone by given input control condition (see note).
    1.1. Open a given game on the smartphone.
    1.2. Orientation for given instruction.
    1.3. Start and play the game.
    1.4. Once the game is over, the researcher will collect data (Level achievement, accuracy rating, health rating, kill rating and total)

Note:
Participants in each group will conduct the same game in different input control conditions.
Group A: iFighter 1945 (Touch with finger input control)
Group B: iFighter 1945 (Touch with finger input control on the virtual interface)
Group C: iFighter 1945 (Touch with touch-pen input control)
Group D: iFighter 1945 (Touch with joypad on the virtual interface)

GROUP E, F, G, AND H (TWO HANDS INPUT CONTROL)

Task List:

1. Play a given game on the smartphone by given input control condition (see note).
    1.1. Open a given game on the smartphone.
    1.2. Orientation for given instruction.
    1.3. Start and play the game.
    1.4. Once the game is over, the researcher will collect data (Level achievement, accuracy rating, health rating, kill rating and total)

Note:
Participants in each group will conduct the same game in different input control conditions.
Group E: Tank Hero (Touch with finger input control)
Group F: Tank Hero (Touch with finger input control on the virtual interface)
Group G: Tank Hero (Touch with finger and touch-pen input control)
Group H Tank Hero (Touch with joypad and touch-pen on the virtual interface)

GROUP E-1 (SPENDING 15 MINUTES FOR THE PRE-EXERCISE)

Task List:

1. Play a given game on the smartphone by given input control condition (see note).
    1.1. Open a given game on the smartphone.
    1.2. Orientation for given instruction.
    1.3. Play the game as a pre-exercise for 15 minutes.
    1.4. Start and play the game for the actual test.
    1.4. Once the game is over, the researcher will collect data (Level achievement, accuracy rating, health rating, kill rating and total)

Note:
Participants in this group will conduct same procedure from Group E-H.
Task: Tank Hero (Touch with finger input control)

APPENDIX T

EXIT SURVEY

Group A-D

	Questions		1	2	3	4	5	
1.	Overall, how easy was it to change directions?	Easy						Difficult
2.	Overall, how easy was it to change movements?	Easy						Difficult
3.	Overall, how easy was it to see contents on the screen while you are controlling interfaces?	Easy						Difficult
4.	Overall, how comfortable was it to hold a smartphone during a playing a game?	Comfort						Discomfort

Group E-H

	Questions		1	2	3	4	5	
1.	Overall, how easy was it to change directions?	Easy						Difficult
2.	Overall, how easy was it to change movements?	Easy						Difficult
3.	Overall, how easy was it to see contents on the screen while you are controlling interfaces?	Easy						Difficult
4.	Overall, how easy was it to aim the target in shooting?	Easy						Difficult
5.	Overall, how easy was it to control both movement and shooting at the same time?	Easy						Difficult
6.	Overall, how comfortable was it to hold a smartphone during a playing a game?	Comfort						Discomfort

Open-ended Survey Questions

1. What did you like most about input control tasks during gameplay? Why?
2. What did you find most frustrating about input control tasks during gameplay? Why?
3. Have you ever used any physical controller for smartphone games? If yes, what was it? Why did you use it?
4. Are you willing to use a physical controller for smartphone games? Why?
5. Do you perceive any different input control reaction between arcade and smartphone game environment (e.g., input control, comfortable level, achievement difficulty, playing methods, etc.)?
6. What strategy did you find to achieve a better game level?